2015 NATIONAL PORK RETAIL BENCHMARKING STUDY

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Laura Anne Bachmeier

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Animal Science
Option:
Meat Science

May 2016

Fargo, North Dakota

North Dakota State University
Graduate School

Title

2015 NATIONAL PORK RETAIL BENCHMARKING STUDY

By

Laura Anne Bachmeier

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. David Newman
Chair

Dr. Eric Berg

Dr. Kasey Maddock-Carlin

Dr. Harlene Hatterman-Valenti

Approved:

May 2nd, 2016
Date

Dr. Gregory Lardy
Department Chair

ABSTRACT

The objective of this study was to quantify pork quality variation in the retail self-serve meat case nationwide. Center-cut loin chops (CCLC) (n=3795) were analyzed in-store for subjective color and marbling scores (2.85 and 2.30). Means for enhanced (EN) and non-enhanced (NON) CCLC were: L* (54.46 vs. 55.99; $P < 0.0001$), pH (6.00 vs. 5.74; $P < 0.0001$), and Warner-Bratzler Shear Force (WBSF) (20.43 vs. 25.99 N; $P < 0.0001$). Mean EN and NON sirloin chop values were: L* (53.74 vs. 52.51; $P = 0.20$), pH (6.00 vs. 5.89; $P = 0.04$), and WBSF (16.18 vs. 22.92 N; $P < 0.0001$). Mean EN and NON blade steak values were L* (45.81 vs. 45.96; $P = 0.82$), pH (6.42 vs. 6.28; $P = 0.04$), WBSF (15.74 vs. 19.42 N; $P = 0.0005$). Results indicate a large amount of variation exists in the pork retail self-serve meat case.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to my family for their unconditional love and support during my time as a graduate student, as well as in life. I wouldn’t be able to venture through this journey alone without all of your continuous dedication. Dad and mom, thank you for always being there to talk about agriculture with me, always being good listeners, and your compassionate words of endless positive energy sent my direction to keep doing my best. Rachel, thank you for being the best older sister a girl could ever have. I have always looked up to you as a mentor and successful woman. Six years of your life was dedicated to pharmacy school. Every moment you always worked your hardest to reach your dreams, which has helped me enable to reach my goals in school too.

Secondly, I would like to extend an acknowledgement to the North Dakota State University Animal Sciences Department faculty and staff. As well as, the Newman lab and other Animal Science graduate students who continually supported me with my research, and lasting friendships. Additionally, thank you Christina Hayes for being a part of this research, being a mentor as well as a dear friend who always makes me laugh and cry tears of joy by all your kind words.

I would like to extend an enormous thanks to my major professor Dr. David Newman for providing me with the opportunity to work with someone so well known in the swine industry and provide me endless prospects to help me grow as an individual in my professional career. Thank you for your continuous support and encouragement during my master’s degree.

Lastly, I would like to thank the National Pork Board for funding this research project to enable me to conduct a nationwide project that aids in making continuous improvement for the swine industry I dearly am passionate about.

DEDICATION

I would like to dedicate this thesis to my grandfather Paul David Mahoney and cousin Jason Hartman.

TABLE OF CONTENTS

ABSTRACT ... iii

ACKNOWLEDGEMENTS ... iv

DEDICATION ... v

LIST OF TABLES ... ix

LIST OF FIGURES ... x

LIST OF ABBREVIATIONS ... xi

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW ... 1

Introduction ... 1

Pork Color ... 2

Pork pH and Water-Holding Capacity ... 9

Pork Marbling ... 11

Pork Tenderness ... 12

Enhancement Type ... 14

Consumer Preference ... 16

Benchmarking Pork Quality ... 17

Literature Cited ... 19

CHAPTER 2. NATIONAL PORK RETAIL BENCHMARKING STUDY: CENTER-CUT LOIN CHOP, SIRLOIN CHOP, AND BLADE STEAK ANALYSIS ... 27

Abstract ... 27

Materials and Methods ... 28

Retail Store Selection and Sampling ... 28

In-Store Subjective Assessment ... 31

In-Laboratory Subjective Measurements ... 32

Instrumental Color Measurement ... 33

pH Measurement ... 33

Warner-Bratzler Shear Force and Cook-Loss Percentage Measurements 34

Statistical Analysis 35

Results and Discussion 35

Product Demographics 35

Subjective Pork Quality Attributes 36

Instrumental Pork Quality Attributes 44

Pork Quality Attributes Frequency Distributions 47

Pork Quality Attributes Correlation Coefficients 59

Conclusions 61

Literature Cited 62

CHAPTER 3. COMPARISON OF 2012 NATIONAL PORK RETAIL BENCHMARKING STUDY VERSUS 2015 NATIONAL PORK RETAIL BENCHMARKING STUDY 64

Abstract 64

2012 Materials and Methods 65

Retail Store Selection and Sampling 65

In-Laboratory Subjective Measurements 66

Minolta Color and pH Measurements 66

Warner-Bratzler Shear Force 67

Statistical Analysis 68

2015 Materials and Methods 68

Retail Store Selection and Sampling 68

In-Store Subjective Assessment 70

In-Laboratory Subjective Measurements 71

Instrumental Color Measurement 72

pH Measurement 72

Warner-Bratzler Shear Force and Cook-Loss Percentage Measurements 72

Statistical Analysis 74
Results and Discussion 74
Product Demographics 74
Subjective Pork Quality Attributes 77
Instrumental Pork Quality Attributes 84
Pork Quality Frequency Distributions 93
Conclusion 99
Literature Cited 99
CHAPTER 4. OVERALL CONCLUSIONS AND IMPLICATIONS 101

LIST OF TABLES

Table Page

2.1. Identification of cities included in retail store sampling by region ……………………..…29

2.2. Center-cut loin chop, sirloin chop, and blade steak demographics by region across the United States ……………………………………………………………………….…....30

2.3. National representation of simple statistics of center-cut loin chop, sirloin chop, and blade steak quality attributes ……………………………….………………………….…...37

2.4. Least square means (S.E.) of enhanced (EN) and non-enhanced (NON) center-cut loin chop, sirloin chop, and blade steak quality attributes nationwide ……………….....40

2.5. Least square means (S.E.) per region of enhanced (EN) and non-enhanced (NON) center- cut loin chop, sirloin chop, and blade steak quality attributes ……………….....41

2.6. Correlations of L*, a*, b*, pH, and Warner-Bratzler Shear Force (WBSF) in center-cut loin chops, sirloin chops, and blade steaks ……………………………………….....60

3.1. 2012 Center-cut loin chop, sirloin chop, and blade steak demographics by region across the United States ……………………………………………………………...75

3.2. 2012 National representation of simple statistics of center-cut loin chop, sirloin chop, and blade steak quality attributes ……………………………………………………..78

3.3. 2012 Least square means (S.E.) of enhanced (EN) and non-enhanced (NON) center-cut loin chop, sirloin chop, and blade steak quality attributes nationwide ……………...79

3.4. 2012 Least square means (S.E.) per region of enhanced (EN) and non-enhanced (NON) center- cut loin chop, sirloin chop, and blade steak quality attributes …………..82

LIST OF FIGURES

Figure Page

2.1. Frequency distribution of subjective color score measured in-laboratory of enhanced (EN) and non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks 49

2.2. Frequency distribution of subjective marbling score measured of enhanced (EN) and non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks 52

2.3. Minolta L* frequency distribution of enhanced (EN) and non-enhanced (NON) a) center- cut loin chops, b) sirloin chops, and c) blade steaks 54

2.4. Frequency distribution of pH of enhanced (EN) and non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks 55

2.5. Frequency distribution of Warner-Bratzler Shear Force (WBSF) measured in-laboratory of enhanced (EN) and non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks 58

3.1. Frequency distribution of subjective color scores from 2012, and 2015 in-store (S), and in-laboratory (L) for enhanced (EN) and non-enhanced (NON) center-cut loin chops 93

3.2. Frequency distribution of subjective marbling scores from 2012, and 2015 in-store (S), and in-laboratory (L) for enhanced (EN) and non-enhanced (NON) center-cut loin chops 95

3.3. Minolta L* frequency distribution from 2012, and 2015 of enhanced (EN) and non-enhanced (NON) center-cut loin chops 96

3.4. Frequency distribution of pH from 2012, and 2015 of enhanced (EN) and non-enhanced (NON) center-cut loin chops 97

3.5. Warner-Bratzler Shear Force frequency distribution from 2012, and 2015 of enhanced (EN) and non-enhanced (NON) center-cut loin chops 98

LIST OF ABBREVIATIONS

RFN	Red, Firm, and Normal
PSE	Pale, Soft, and Exudative
DFD	Dark, Firm, and Dry
HAL	Halothane Gene
PSS	Porcine Stress Syndrome
RN^-	Rendement Napole Gene
ACTH	Adrenocorticotropic Hormone
ATP	Adenosine Tri Phosphate
ADP	Adenosine Di Phosphate
CP	Creatine Phosphate
pI	Isoelectric Point
WHC	Water-Holding Capacity
IMF	Intramuscular Fat
SSF	Slice Shear Force
WBSF	Warner-Bratzler Shear Force
EN	Enhanced
NON	Non-Enhanced
C	Celsius
F	Fahrenheit

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

Introduction

Fresh pork color, pH, water-holding capacity, marbling, tenderness and enhancement type are attributes associated with pork quality. One parameter alone cannot define pork quality. Each segment of production within the swine industry measures pork quality differently. However, the end goal for each segment is to provide consumers with wholesome pork products. Yet, individual consumers use a variety of ways to determine the quality of pork. Appraised physical factors include color, marbling, subcutaneous fat, and the amount of exudation in package, type of packing, if the product is bone-in or boneless, firmness, and odor. While sensory factors include tenderness, juiciness, and flavor of the meat once cooked. Mancini (2005) described a complexity regarding the appearance of meat due to animal genetics, ante- and post-mortem conditions, fundamental muscle chemistry, as well as other factors associated with meat processing like packaging, distribution conditions, storage, display and final preparation for consumption. Consumer judgement is unique to every individual (Jeremiah, 2001). Purchasing decisions are impacted more by product appearance compared to any other quality factor (Tapp, 2011). Appearance has a great influence on how meat, including pork, is valued by the customer (Fortomaris et al., 2006). Consumers have trouble evaluating pork quality, and become uncertain (Grunert et al., 2004) as they are misinformed on quality attributes and overall lack of confidence (Papanagiotou et al., 2013). Pork quality traits are difficult to measure since there are many complex factors, particularly when endeavoring to improve pork quality (Huff- Lonergan et al., 2002).

Pork quality is important for the entire swine industry especially in attempting to meet the National Pork Board (NPB, 2014) Specific/single outcome, Measureable, Achievable, Relevant/realistic and Time bound (SMART) objectives. Specifically, the SMART objectives consists of three main goals: “build customer trust, drive sustainable production and grow consumer demand. Under growing consumer demand, a more detailed goal is to reduce the percentage of pork loin chops scoring below the National Pork Board’s color score 3 by 10 percent by the year 2020 (55 percent reduced to 45 percent)” (NPB, 2014). Therefore, benchmarking for pork quality is imperative to determine the quality of pork that the swine industry is actually providing consumers.

Pork Color

Myoglobin, a heme protein, is the pigment of muscle that gives meat its red color. Myoglobin constitutes 80 to 90 percent of the total pigment (Hedrick et al., 1989). When myoglobin is denatured, the color strength is reduced (Lonergan, 2008). Myoglobin is a water soluble protein that exists in three chemical states in fresh pork which are associated with the presence or absence of oxygen and the oxidation state of the central ion atoms: deoxymyoglobin, oxymyoglobin and metmyoglobin. Deoxymyoglobin is the state where the meat is purple due to the lack of oxygen. Once exposed to air and given a bloom time of 10 to 15 minutes, the chemical state switches to oxymyoglobin turning the meat color to red. Finally, after prolonged exposure over days, the meat color turns brown when at the metmyoglobin stage. The shift of purple to red is a result of myoglobin absorption of oxygen (Brewer et al., 2006). Thus, there is the ability to control the color of meat based on the environment it is exposed to, packaged or stored.

The consistency of fresh pork color in the pork retail self-service display case can influence the consumer’s decision to purchase pork products. Color is the most important characteristic consumers deliberate when buying pork (Tan et al. 2000; Barbut, 2001; Font-i-

Furnols et al. 2012). Typically, consumers will buy pork that is darker versus lighter in color (Brewer & McKeith, 1999; Norman et al., 2003). Consumers evaluate the ‘value’ or quality of pork from their individual expectations of the product and past experience (Brewer, 2001a). Therefore, in making purchasing decisions, if a consumer is dissatisfied due to a poor eating experience from pork, they have the option to choose another meat source (i.e. chicken or beef). Consumers prefer pork that is lean, has a consistent color, and little amount of water on the cut surface or in-package (Mabry & Bass, 1998) because they use discoloration and water-loss as a determination of freshness (Mancini & Hunt, 2005). This agrees with the findings from Buege et al. (2003) that consumers avoid pork that appears to have unusual and variable lean color and excessive amount of purge in the package. Therefore, it’s imperative to quantify pork color.

Fresh pork color can be quantified through a multitude of subjective and instrumental measurements. Many pork processors visually inspect color on the processing line to sort various pork retail cuts to sell to either domestic or export markets (Forrest, 1998). Subjective color is measured by an experienced grader using the National Pork Board Color Standards (NPB, 2011). The scale ranges from one to six. A pork cut with a color score of 1 appears pale, pinkish gray to white in its appearance, while a color score of 6 appears dark, purplish red. Wright et al. (2005) determined an average mean color score of boneless loin chops was 3.52 (± 0.85). Moeller et al. (2010a) reported a mean subjective color score of 3.13 (± 1.04) in loin chops. Newman (2012) reported a mean color score in center-cut loin chops of 3.12 (± 0.85). Brewer (2001c) reported higher marbled chops were lighter in color (2.42 ± 0.94) than low and medium marbled chops due to the mixture of white from the marbling and pink color from myoglobin causing more reflection on the surface when observed for color scoring, suggesting, subjective color scores have decreased.

Pork color can also be evaluated instrumentally. By instrumentally measuring fresh pork color, it reduces human error, is more accurate, and less time consuming. Instrumental color can be assessed using a spectrophotometer or colorimeter. There are two commercially available colorimeters; Hunterlab (Hunter Associates Laboratory Inc., Reston, VA) or Minolta Colorimeter (Minolta Company, Ramsey, NJ). These instrumental devices measure the amount of light reflected from the pork muscle. Free water on the cut surface causes more light reflectance, resulting in lighter pork color. Light can either be absorbed, reflected or scattered on the cut surface of meat (Hughes et al., 2014; Huff- Lonergan & Page, 2001). Colorimeters measure *CIE* L*, a*, and b* color space values. L* measures the lightness to darkness (100 = white; 0 = black). Brewer & McKeith (1999) reported a normal L* value 51.51 (±.0.81) for *longissimus thoracis* and *lumborum*. Brewer et al. (2001b) concluded L* was not prejudiced by bloom time, indicating it is the best value to determine if a carcass is predisposed to becoming pale, soft, and exudative (PSE) or dark, firm, and dry (DFD) pork. Hunter L* and Minolta L* values are not affected by bloom time, but decrease with pH (Brewer et al., 2006). Furthermore, The Pig Improvement Company (2003) reported preferred Minolta L* scores range from 42 to 46. As Minolta L* values decrease, subjective color increases and vice versa, as Minolta L* increases, subjective color decreases. According to the NPB (2011), an L* value of 53 represents a subjective color score of 3. Minolta a* measures the redness to greenness (+ a = red; - a = green). A more positive a* measures red, a more negative a* measures green. Minolta b* measures the yellowness to blueness (+ b = yellow; - b = blue). A more positive b* measures yellow and a more negative b* measures blue.

The National Pork Board has established pork quality standards in which it describes three types of pork quality; red, firm and non-exudative (RFN), pale, soft and exudative (PSE) and dark, firm, dry (DFD). The quality standards define fresh pork's color, texture and ability to bind water.

Ideally, the pork industry would prefer to provide consumers with RFN pork, which is pork that has a reddish-pink color, is firm in its texture, and displays no exudation on the cut surface or in package. These characteristics of RFN pork are due to the fact that the meat from the carcass has an optimal pH value where proteins like myoglobin, actin, or myosin are not denatured in the process of the conversion of muscle to meat. It has a more reddish-pink color since more myoglobin is present in the muscle, a more firm texture as the muscle fibers are more evenly spaced, and contractile proteins are unstable to bind an appropriate amount of water.

Abnormalities in pork quality include PSE and DFD pork. Pale, soft, and exudative pork is not desirable to consumers therefore contributes a large loss to the pork industry. Kauffman et al. (1992) reported in the U.S. 16 % of carcasses were PSE, while Cannon et al. (1996) reported 10.2 % of carcasses are PSE. Yet, according to Stetzer and McKeith (2003) approximately 15.5 % of the pork produced in the United States in 2003 had the characteristics of PSE like pork. Pale, soft, and, exudative pork is created when the process of anaerobic glycolysis occurs at a rapid rate, resulting in a rapid pH decline, lower processing yields, increased cook loss percentage and reduces juiciness (Hedrick et al., 1989). As the name PSE implies, the color appearance displays pale or white lean color, typically having a subjective color score equal to or less than 1.0. Pale, soft, and exudative pork is also more prone to display discoloration of green and grey color (Buege, 2003). Furthermore, the texture is very soft, and doesn't hold its shape due to the unfolding of actin and myosin causing the proteins to denature due to the high degree of conformational entropy and relatively high free energy not allowing the proteins to bind to water. Therefore, due to the poor water-holding capacity, there is an excess amount of exudation on the cut surface, in the pork package, and once cooked PSE pork loses additional water, therefore from a palatability standpoint, it is tough and dry.

Every aspect a pig encounters throughout their lifetime can influence the consistency and quality of pork. Therefore, it could be said that pork producers have 50 % of the influence and pork packers have 50 % of the impact on the quality of pork (Grandin, 2000). Producers select the genetics, nutrition, pre-slaughter handling and transportation that affects the quality of pork. Packers can impact the quality of an animal's carcass through on-site handling, time in lairage, method of slaughter, time required to exsanguinate, and chilling rate. Various factors that influence the individual animal throughout an animal's lifetime can impact the quality of the carcass in terms of converting muscle to meat. These factors are crucial to provide RFN pork rather than PSE or DFD pork. First, before a market animal is even born, the producer must consider selecting genetics for traits which encompass breed, heritability, and specific genes associated with certain terminal and maternal lines. One particular autosomal recessive gene found in the pig genome that impacts pork quality, but more specifically a contributor to PSE meat, is the Halothane Gene (HAL), or also referred to as porcine stress syndrome (PSS). The HAL gene accounts for 25-35 % of PSE carcasses (Allison, Johnson & Doumit, 2005). The muscles cannot regulate the release of Ca^{2+} from the sarcoplasmic reticulum due to a malfunction on other calcium channels (Bowker et al., 2000; Scheffler & Gerrard, 2007). One benefit to the HAL gene is increased muscle lean. Yet, Norman (2002) reported producing lean pork can lead to PSE carcasses. The Rendement Napole (RN^-) gene is another gene typically found in Hampshire swine that negatively impacts numerous pork quality traits (Miller, 2002). Carr et al. (2014) reported RN^- gene pigs significantly had greater glycolytic potential values, higher drip loss percentage, higher Minolta a* values and lower pH values than *Longissimus* samples from non-carrier pigs due to increased glycogen storage.

Biochemically, how swine are handled prior to slaughter can impact the quality of pork as it is converted from muscle to meat. It is well known that porcine are susceptible to stress. Thus, the amounts of stress a pig experiences results in a PSE carcass. Varying situations that cause acute stress can be co-mingling pigs, use of a hot shot on sensitive body parts, ground surface, different lighting, moving pigs in large crowds (Norman, 2002) with unfamiliar animals down narrow alleyways, traveling up steep trailer ramps, or even being exposed to loud or unknown noises. As the animal becomes increasingly stressed, they respond with the fight or flight mechanism. First, there is an endocrine response from the sympathetic nervous system that releases adrenaline (cortisol) from the adrenocorticotropic hormone (ACTH) in the brain signaling the body to mobilize energy. As the animal becomes increasingly stressed, their body requires more adenosine triphosphate (ATP), adenosine diphosphate (ADP), or creatine phosphate (CP) to contract muscles. The ATP is produced by carbohydrates. When oxygen is present, glycogen a polysaccharide (20 + unit sugar) is the storage form of glucose. Glucose is converted to ATP by the process of glycolysis and, when under oxygen deprivation produces lactate in the muscle, which travels through the blood steam into the liver where it is eventually extracted. In addition to this conversion, free inorganic phosphates and ADP convert to ATP in the muscle. Yet, once the animal is rendered unconscious and exsanguinated, the blood flow stops. Therefore, the stored glycogen is going to produce an accumulation of lactic acid in the muscle, resulting in a prompt pH drop until glycogen or ATP stop functioning. Rapid glycolysis also generates significant amounts of heat, which increases the carcass temperature (Du & McCormick, 2009). In conjunction with a rapidly declining pH and high carcass temperature, this results in denaturing of the proteins, especially myosin. Postmortem, the carcass temperature decreases under refrigeration. The amount of lactic acid and enzymes produced causes a more acidic pH. With the increase in rate of glycolysis due to stress at slaughter, lactic acid accumulates more rapidly, resulting in a faster than normal rate of pH decline. The accelerated rate of pH decline occurs until it nears meats isoelectric point of 5.1. This combined with a high carcass temperature that is closer to living body temperature, causes denaturing in proteins and ultimately ensues in PSE pork as the denatured proteins myosin and actin don't absorb the light but now reflect it, resulting in a more pale product.

Processors additionally have impact on pork quality, including their animal handling techniques, harvest method (i.e. electrical stunning or CO_2 gas), time in lairage, and chilling rates to name a few. Grandin (1994) reported pigs should be kept in lairage 2-4 hours before harvested to recover from any stress experienced prior to slaughter. Lesiow and Xiong (2013) reported that delaying carcass chilling can lead to PSE carcasses. Some processing facilities have utilized in blast chilling carcasses to reduce the amount of PSE carcasses present (Huff-Lonergan & Page, 2002).

Contrary to PSE pork, there is Dark, Firm, Dry (DFD) pork. It is similar in appearance to 'dark cutters' in beef. Dark color is often associated with lack of freshness (Hedrick et al., 1989). Dark, firm, and dry pork is caused by chronic stress that ranges from minutes to hours, as opposed to acute stress observed in PSE pork. The long term stress events like extended transport of pigs. Gajana et al. (2013) reported that higher risk incidences of PSE pork occurred when pigs were transported during the autumn season, with transportation time >1 hour 30 minutes and space allowance increased from 0.4 m2 per 100 kg. Additionally, prior to slaughter, due to long term stress, the muscle glycogen was depleted. Dark, firm, and dry pork pH declines at a slower extent. Therefore, proteins are not denatured, are able to bind more free water, resulting in a greater water-holding capacity, and ultimately a darker, firmer product (Miller, 2002). Plus, due to the higher pH value postmortem, typically DFD pork has a shorter shelf life in the retail meat case due to more bacterial growth and results in consumers avoiding this product.

Pork pH and Water-Holding Capacity

The rate at which pH declines can greatly affect the quality of meat. pH is defined as the negative logarithmic of hydrogen ion concentration, also referred to as the acid-base relationship. pH= -log [H+]. pH is measured on a scale of 1 to 14. A neutral pH, and the pH of living tissue is 7.0. A pH value above 7.0 is basic, while a pH value below 7.0 is acidic. During the conversion of muscle to meat, pH is typically measured at two increments. Initial pH is measured 30 minutes to 1-hour post-mortem, followed by ultimate pH, which is measured 24-hours post-mortem. However, for research purposes, it is difficult to collect pH values due to the high line speed at packing facilities (Meisinger, 2008). Various studies have reported different ranges for initial and ultimate pH values. Overall, it's important to realize DFD pork has a slow, gradual pH decline, RFN pork has a moderate pH decline and PSE pork has a very rapid pH decline. The rate at which glycolysis occurs can impact the pH of a pork carcass. The amount of glycogen present in the muscle after exsanguination is broken down and directly correlated to the amount of lactic acid (Lonergan, 2008). Thus, more glycogen in the muscle results in a lower ultimate pH (Lonergan, 2008). Forrest (1998), reported measuring pH 45-minutes postharvest is a proven method to early detection of PSE pork. O'Neill et al. (2003) reported if an initial pH at 45-minutes postmortem is less then often 5.7-6.0 results in PSE carcasses. A low ultimate pH reflects more light causing a lower subjective and instrumental color score, because the light is not absorbed (Huff-Lonergan et al., 2002). The Pig Improvement Company (2003) reported PSE pork has an initial pH below 5.8, and an ultimate pH below 5.5, and ideal ranges for initial pH should range from 6.7 to 6.3 and ultimate pH to be 6.1 to 5.7. Additionally, Forrest (1998), reported 99% of pork will be PSE like pork if the ultimate pH is 5.5 or lower. Bidner et al. (1999) reported ultimate pH and L* were significantly correlated (r = -0.68). Bidner et al. (2004) indicated 57.4% of loins had an ultimate pH between 5.4 and 6.1. Moeller et al. (2010) reported an ultimate pH near 5.40 reduced consumer's satisfaction, while a pH up to 6.40 increases the amount of juiciness, tenderness and flavor factors. Furthermore, a study by Aberle et al. (2001) showed that ultimate pH is related to water holding capacity. A higher pH holds more free water, to increase cook yield. Proteins are responsible for binding water (Lonergan, 2008) which influences meats texture and color. Two major proteins, actin and myosin, within the muscle can denature and lose their secondary and tertiary protein structure during post-mortem as the carcass is chilling and pH drops. At a pH of 5.1, the proteins have no net charge (Lonergan, 2008). Yet, Huff-Lonergan and Lonergan (2005) reported when the pH nears the isoelectric point (pI) of 5.4 there is no net charge due to the negative and positive charges being equal to one another, causing a decrease in the water holding capacity of raw meat. Once water binds to proteins with zero net charge, the amount of water attracted to muscle proteins decrease. Barbut et al. (2008) also reported ultimate pH is correlated with water-holding capacity. The amount of water pork muscles retain is defined as water-holding capacity (WHC). The amount of water-holding capacity a pork muscle has can be measured by its amount of drip loss, purge loss or cook loss. About 75% of water is in post-rigor muscle (Hughes et al., 2014). The Pig Improvement Company (2003) reported above 5% drip loss and above 35% cook loss and greater than 3% purge in whole loin packages designates a pork quality problem. Huff-Lonergan et al. (2002)

reported a higher ultimate pH results in darker color and reduced drip loss. Vice versa, a lower ultimate pH will result in more exudation, causing more light to be reflected, instead of absorbed.

Pork Marbling

The intramuscular fat within the muscle fiber bundles of meat is called marbling. Intramuscular fat content is measured chemically, while subjective marbling scores are given by an experienced grader (Jeremiah, 2001) using the National Pork Board Marbling Standards (NPB, 2011). The marbling standards are estimated on a range of one to ten to signify the minimum percentage degree for each score. A marbling score of one is practically devoid of intramuscular fat, while a ten has an abundant amount of marbling on the loin chop surface. The experienced grader evaluates the amount of fat deposited based on the number, size, shape, and assigned a score 1-10.

The amount of marbling present may be influenced by the amount of connective tissue, genetics, sex, age, or even type or time amount the pigs are on a certain diet. Collagen and elastin are the proteins components in connective tissue (Monin, 1998). There is currently a tendency in the swine industry to select swine genetics the produce more efficient swine that are leaner and more expressively muscled. Huff-Lonergan et al. (2002) reported hogs that have a higher percent lean have carcasses exhibiting less marbling in pork chops as compared to hogs that have carcasses with more 10th rib backfat. Additionally, gilts tend to have a higher percent lean than barrows.

DeVol et al. (1988) showed that IMF and tenderness are correlated (r=0.34) when evaluated by a trained taste panel because lower IMF levels correlated to tougher meat. Cannata et al. (2012) reported when IMF was 2.5% or greater, tenderness and juiciness increased. Similarly, Fernandaz et al. (1999a) reported when IMF values reached 2.5 % juiciness and flavor was enhanced. As well, Brewer et al. (2001c) reported chops with 3 to 5 % IMF were more juicy, tender and flavorful than lower marbled chops that had 1 to 1.5 % IMF, although consumers accepted purchasing lower marbled chops. Moeller et al. (2010a) reported a mean value for IMF percent of 3.01 (± 1.41) in pork loins. Furthermore, Font-i-Furnols et al. (2012) recommended 2.2-3.4 % minimum IMF in pork loins improves consumers' satisfaction. Rincker (2008) concluded that nearly 50% of the consumers in a consumer panel selected pork loin chops in a display case with the least amount of marbling and said they would purchase pork that is leaner. These findings support Jeremiah (2001) stating that consumers request a small amount of visual IMF, while still having an acceptable eating experience. Moeller et al. (2010b) suggested IMF levels of 5-6% would improve pork flavor, but contribute very little or have no influence on consumer's perceptions of juiciness or tenderness attributes. Brewer (2001c) reported low and medium marbled chops were more accepting than highly marbled chops as well as for consumers purchase intent. Fernandez et al. (1999) reported that as the amount of intramuscular fat increased, consumers' responses decreased for positive answers in response of willingness to eat. From the same study, as intramuscular fat increased to up 3.5%, consumer's responses for texture and taste were more satisfactory. Yet, from the second experiment in the study, intramuscular fat levels were unaffected when loin chops were trimmed of external fat. These findings also agree with Wright et al. (2005) where consumers purchase intent increased with highly marbled pork, resulting in the pork to be more tender, juicy and flavorful.

Pork Tenderness

In general, consumers prefer tender pork (Aaslyng et al., 2007; Norman et al., 2003) while some consider tenderness to be the most important factor associated to the palatability of pork (Koohmaraie, 1996; Koohmaraie et al., 2002; Koohmaraie et al., 2006). Tenderness deals with the skeletal muscle structure and biochemistry. Measuring pork tenderness via trained sensory panels, or consumer panels is time consuming and costly, so instrumentally measuring tenderness is a more consistent way to quantify tenderness. There are a variety of ways to instrumentally measure pork tenderness, which includes the Warner-Bratzler Shear Force (WBSF), slice shear force (SSF), or the star probe method. The SSF method was developed by Shackelford et al. (1999b). Shackelford et al. (2004a) compared SSF and WBSF in pork loins and determined SSF had a higher coefficient of variation (32%) then WBSF (19%) in determining pork tenderness in the *Longissimus* muscle. The WBSF method measures the force necessary to shear through a cored piece of meat parallel to the muscle fibers of cooked meat against a dull blade. A lower shear force value represents more tender pork, whereas a higher shear force value represents a more tough pork product. The method is designed to mimic a consumer biting down on a piece of pork. Moeller et al. (2010b) reported trained sensory panelists favored pork with a WBSF value less than 24.5 N, as it was more tender. From the same study, consumers' acceptability decreased by 4% for every 4.9 N increase above 24.5 N, as panelist responses determined the pork was more tough. Norman et al. (2003) reported trained panelists found a more tender and juicy product when evaluating darker colored pork compared to lighter colored pork. Wheeler et al. (1994) reported the orientation of the core to the muscle fibers and cooking method conditions significantly influenced the shear force values reported. As well, Wheeler et al. (1996) determined after 5 cores in steaks, there was little difference in WBSF values.

Meat tenderness is determined by the amount of connective tissue, IMF content, and myofibrillar structure (Laack, Stevens, & Stalder, 2001). Intrinsic factors that influence pork tenderness include sarcomere length, the amount of connective tissue (perimysium), marbling content, and location of muscle. The shorter the sarcomere length, the more tough meat is due to the bulk density caused by lack of myofibrillar spacing between actin and myosin (Hughes et al., 2014). Additionally, the decreased spacing between the sarcomere results in more moisture loss and ultimately once pork is cooked will have negative sensory characteristics because the pork tastes drier. Wheeler et al. (2000) evaluated 5 pork muscles (*Semitendinosus, Triceps brachii, Longissimus, Semimembranosus*, and *Biceps femoris*) to determine the differences in tenderness based on sarcomere length and the amount of collagen and intact desmin present. The results indicated the various muscles had different tenderness values and that tenderness and connective tissue amount are highly correlated (Wheeler et al., 2000). From the perspective of a pig carcass, there are muscles of locomotion, as well as muscles of posture. The muscles of locomotion include the picnic shoulder, Boston butt and ham, which are more commonly used for movement. These muscles tend to be more glycolytic and used for strength, and have more connective tissue, therefore tend to be less tender. While the muscles of posture include the loin, do less work so as a result, tend to be more tender.

Enhancement Type

The pork industry has implemented the use of enhancement, or the addition of non-meat ingredients like water, salt, sodium phosphate, sodium lactate, potassium lactate, sodium diacetate (Miller, 2002) to fresh pork primals and subprimals in a water-based solution, to improve the juiciness, tenderness, and flavor of pork, As the degree of doneness increases, enhancement has been shown to have a protective effect on pork palatability (Moeller et al., 2009). Over the last 10 years, non-enhanced pork represents 55.1 % and enhanced pork represents 44.9 % of fresh pork at the retail level (Reicks et al., 2008). Reicks et al. (2008) also noted compared to any other protein, pork significantly ($P < 0.001$) represents the largest amount of enhanced product in the retail meat case. A Snapshot of Today's Retail Meat Case (2010) reported since 2004 to 2010, enhanced pork available to consumers decreased by 6 %. The trend for marketing non-enhanced pork is expected to increase due to potential health concerns associated with eating pork products enhanced with sodium and phosphate (McEwen & Mandell, 2011). Advantages to enhancing pork include improving pH (Sheard et al., 1999), pork color, increasing water-holding capacity, tenderness, and juiciness (Miller, 2002), as well as the shelf life of pork as it reduces the browning of the meat while stored. Wright et al. (2005) determined enhanced boneless pork loin chops were darker in color with a mean NPB color score of 3.59 (± 0.05) as compared to non-enhanced boneless pork loins having a mean NPB color score of 3.46 (± 0.05). Phosphates increase the water-holding capacity of meat (Hedrick et al., 1989). Lonergan (2008) reported that adding salt, another non-meat ingredient to the myofibrillar proteins in muscle increases water-holding capacity. Furthermore, Sheard et al. (1999) reported adding 0.25-0.5 grams of polyphosphate per 100 gram of pork steaks improves tenderness and juiciness. These results agree with Prestat et al. (2002) that enhancing pork increases tenderness, juiciness, and flavor. Brewer et al. (2002) recommended that adding 6-12 % of solution improves pork quality. While Miller (2002) reported that 7-15 % of non-meat ingredients are typically added to pork. The USDA/FSIS (2013) requires labeling on packages describing the percent of enhanced solution added to the product. Disadvantages to enhancing pork include the formation of color striping, which visually causes light and dark stripes on the cut surface from the injection of non-meat ingredients. Gooding et al. (2009) reported enhanced longissimus samples had significantly ($P < 0.05$) had higher incidences of striping for various experiments conducted using different brines, brine concentrations, brine temperature enhancement pressure, and enhancement level. Furthermore, enhancement striping occurs immediately, and is difficult to eliminate and a permanent problem (Gooding et al., 2009). Carr et al. (2014) determined eliminating pork quality problems associated with the Rendement Napole gene did not improve after enhancing pork loins. Additionally, consumers are aware of the added sodium in enhanced product versus non-enhanced product. Therefore, marketing non-enhanced pork could potentially increase due to health concerns related with eating pork products enhanced with various solutions.

Consumer Preference

Over the years, there have been many studies (Brewer et al., 2001c; Wright et al., 2005; Ngapo et al., 2007; A Snapshot of Today's Retail Meat Case, 2010; NPB, 2012; Newman, 2012) conducted to determine what pork products consumers prefer, as well as their intent to buy. The National Pork Board conducted a pork purchasing study (NPB, 2012) where they determined consumers add pork to their shopping list as a result of a request, sale or advertisement (in-store, media, marketing, mail) and are particular about where they purchase their pork compared to other protein sources. Iowa State University (McMullen, 2005) studied consumers' preference of three types of pork with different appearances; high pH, low pH, or Berkshire pork. Consumers accepted pork that had a higher pH, followed by Berkshire pork, and lastly lower pH pork when samples were rated on a scale 1-9 for tenderness, juiciness, and flavor (McMullen, 2005). Brewer et al. (2001c) determined consumers will purchase leaner pork, but want pork that is higher marbled to increase sensory characteristics. Ngapo et al. (2007) reported across different countries, women preferred leaner pork then men. Aaslying et al. (2006) concluded that pork color was the only quality parameter that male and female consumers had different opinions on. Males were not influenced by pork color, whereas, females preferred pork color to be more light or grey in color.

Consumers over cook pork (Detienne & Wicker, 1999). Therefore, Moeller et al. (2010a; 2010b) conducted two tests determining pork quality on different end-point cooked temperatures for consumers and trained panelists to determine what type of pork consumers accept, want and prefer. The authors reported WBSF and pH are important to the palatability. Consumer's desired pork loins that were cooked to lower end-point temperature, and had a greater ultimate pH and IMF values which positively impacted palatability of the loins. However, IMF did not influence the consumer's perception of tenderness, juiciness or flavor of the pork (Moeller et al., 2010a; Rincker et al., 2008). By benchmarking what consumers want, based on their preference of lower end-point cooked temperatures, and food safety regulations in May 2011, the USDA/FSIS changed the recommended end-point cooking temperatures of whole cuts of pork of 160°F to 145°F (USDA, 2013) to provide and educate consumers that cooking pork with a lower internal temperature will improve their pork eating experience.

Benchmarking Pork Quality

A variety of benchmarking studies have been conducted relevant to pork quality. In response to the Pork Chain Quality Survey Audit, pork quality attributes were ranked at slaughter to benchmark various pork quality defects. Pearson et al. (2005a) first examined how PSE pork in bone-in and boneless hams influenced the quality. Person et al. (2005b) researched benchmarking value in the pork supply chain, on processing characteristics and consumer evaluations of pork bellies of different thicknesses when manufactured into bacon due to the rapid growth of bacon sales in the 1990's. Subjectively, pork bellies were organized into three distinct thickness groups, thin, average and thick. Ninety-six bellies were assigned to each group, where the bellies were first skinned to determine yield, injected with a curing solution, cooled, and then sliced into bacon with specific dimensions and musculature. It was concluded, that although the larger yields associated with a thick belly were beneficial to the packer, and the consumer response was unfavorable due to an ample amount of fatness. Inversely, the thin to average cuts had reduced yields, however were more appealing to consumers'.

The National Meat Case Studies were first conducted in 2002, 2004 (Reicks et al., 2008), 2007 and then in 2010 (A snapshot of today's retail meat case, 2010). The 2004 benchmarking study focused on the various labeling information, brands, and packaging types and the trends associated for all meat sources consumers were being offered in the retail meat case. Following, in 2010, the 2010 National Meat Case Study was conducted to compare changes evident in the retail meat case. No product was bought in either of the studies. A few major evident differences were the availability of store brands tripled, increased package information regarding cooking recommendations (34 % vs. 39 %), and increased case-ready packages (in pork, 50 % vs. 58 %) (A Snapshot of Today's Retail Meat Case, 2010). Each year of benchmarking the meat case, pork ranked third every year compared to other protein sources (i.e. chicken, beef), 2002 (21 %), 2004 (22 %), 2007 (21 %), and 2010 (20 %) in available linear feet in the self-serve meat case, indicating over the years the linear footage of pork has decreased. Benchmarking in the retail meat case is essential to understand and more effectively meet consumer's demands.

Wright et al. (2005) also benchmarked value in the pork supply chain but in the characterization of US pork in the retail marketplace on both processed and fresh meat. There is a great deal of variation in pork quality values, specifically 12.5 % of pork loin chops in the retail marketplace were quantified as low quality (Wright et al., 2005).

The most recent benchmarking study in 2012 (Newman, 2012) conducted a national benchmarking pork quality retail study to quantify pork quality to determine what consumers are being offered at the retail level. From the 117 retail stores visited, the author reported a mean subjective color score of 3.12 (± 0.85), subjective marbling score of 2.48 (± 0.95), Minolta L* of 55.30 (± 3.70), Minolta a* of 5.89 (± 3.12), Minolta b* of 3.73 (± 1.86), pH value of 5.86 (± 0.27), and WBSF value of 23.39 N (± 6.82) in center-cut loin chops. In sirloin chops the reported mean values were 51.92 (± 3.22) for Minolta L*, 19.50 (± 2.74) for Minolta a*, 10.06 (± 2.63) for Minolta b*, 5.88 (± 0.29) for pH, and 18.71 N (± 5.17) for WBSF. In blade steaks the mean values were 45.27 (± 2.79) for Minolta L*, 19.70 (± 2.12) for Minolta a*, 8.13 (± 1.71) for Minolta b*, 6.22 (± 0.27) for pH, and 17.12 N (± 4.65) for WBSF (Newman, 2012). The results indicated that there is a lot of variation in the retail meat case. In the United States there is currently not a 'pork grading' system established based upon pork quality attributes. However due to the variety of variation in the retail meat case, the future of the pork industry could develop such a system.

Literature Cited

A Snapshot of Today's Retail Meat Case. (2010). Executive Summary. National Meat Case Study. Available online at https://faunalytics.org/feature-article/todays-retail-meat-case-2010-national-meat-case-study/. Accessed September 8, 2014.

Aaslyng, M.D., Oksama, M., Olsen, E.V., Bejerholm, C., Baltzer, M., Andersen, G., Bredie W.L.P., Byrne, D.V., & Gabrielsen, G. (2007). The impact of sensory quality of pork on consumer preference. *Meat Science*, 76, 61-73.

Aberle, E.D., Forrest, J.C., Gerrard, D.E., & Mills, E.W. (2001). *Principles of meat science*. 4th Edition. Kendal/Hunt Publishing, Dubuque, IA.

Allison, C.P., Johnson, R.C., & Doumitt, M.E. (2005). The effects of halothane sensitivity on carcass compositions and meat quality in Halothane 1843- normal pigs. *Journal of Animal Science*, 83, 671-678.

Barbut, S. (2001). Effect of illumination source on the appearance of fresh meat cuts. *Meat Science*, 59, 187-191.

Barbut, S., Sosnicki, A.A., Lonergan, S.M., Knapp, T., Ciobanu, D.C., Gatcliffe, L.J., Huff-Lonergan, E., & Wilson, E.W. (2008). Progress in reducing the pale, soft, and exudative (PSE) problem in pork and poultry meat. *Meat Science*, 79, 46-63.

Bidner, B.S., Ellis, M., Brewer, M.S., Campion, D., Wilson, E.R., & McKeith, F.K. (2004). Effect of ultimate pH on the quality characteristics of pork. *Journal of Muscle Foods*, 15, 139-154.

Bowker, B.C., Grant, A.L., Forrest, J.C., Gerrard, D.E. (2000). Muscle metabolism and PSE Pork. American Society of Animal Science.

Brewer, M.S., & McKeith F.K. (1999). Consumer rated quality characteristics as related to purchase intent of fresh pork. *Journal of Food Science*, 61, No 1 1999.

Brewer, M.S. (2001a). Consumer attitudes towards color and marbling of fresh pork. Fact Sheet. National Pork Board. Des Moines, IA.

Brewer, M.S., Zhu, L.G., Binder, B., Meisinger, D.J., & McKeith, F.K. (2001b). Measuring pork color: effects of bloom time, muscle, pH and relationship to instrumental parameters. *Meat Science*, 57, 169-176.

Brewer, M.S., Zhu, L.G., & McKeith, F.K. (2001c). Marbling Effects on Quality Characteristics of Pork Loin Chops: Consumer Purchase Intent, Visual and Sensory Characteristics. *Meat Science*, 59, 153-163.

Brewer, M.S., Jensen, J., Sosnicki, A.A., Fields, B., Wilson, E., & McKeith, F.K. (2002). The effect of pig genetics on palatability, color and physical characteristics of fresh pork loin chops. *Meat Science*, 61, 249-256.

Brewer, M.S., Novakofski, J., & Freise, K. (2006). Instrumental evaluation of pH effects on ability of pork chops to bloom. *Meat Science*, 72, 596-602.

Buege D. (2003). Variation in pork lean quality. Fact Sheet. National Pork Board.

Cannata, S., Engle, T.E., Moeller, S.J., Zerby, H.N., Radunz, A.E., Green, M.D., Baas, P.D., & Belk, K.E. (2010). Effect of visual marbling on sensory properties and quality traits in pork loin. *Meat Science*, 85, 428-434.

Cannon, J.E., Morgan, J.B., McKeith, F.K., Smith, G.C., Sonkta, S., Heavner, J., & Meeker, D.L. (1996). Pork chain quality audit survey: quantification of pork quality characteristics. *Journal of Muscle Foods*, 7, 29-44.

Carr, C.C., Morgan, J.B., Berg, E.P., Carter, S.D., & Ray F.K. (2014). Growth performance, carcass composition, quality, and enhancement treatment of fresh pork identified through deoxyribonucleic acid market-assisted selection for the Rendement Napole gene. *Journal of Animal Science*, 84, 910-917.

Carr, T.R., Kauffman, R.G., Meeker, D.L., & Meisinger, D.L. (1997). Factors reducing pork value. *Pork Industry Handbook, PIH-135*. West Lafayette, IN: Purdue University Cooperative Extension Service, pp. 1-4.

CIE (Commission Internationale de I'eclairage). (1978). Recommendations on uniform color spaces- color equations, psychometric color terms. Supp. No. 2 to EIC Publ. No. 15 (E-1.3L) 1971 (9TC-1-3), CIE, Paris, France.

Detienne, N.A., & Wicker, L. (1999). Sodium chloride and tripolyphosphate effects on physical and quality characteristics of injected pork loins. *Journal of Food Science*, 64(6), 1042-1047).

DeVol, D.L., McKeith, F.K., Bechtel, P.J., Novakofski, J., Shanks, R.D., & Carr, T.R. (1988). Variation in composition and palatability traits and relationships between muscle characteristics and palatability in a random sample of pork carcasses. *Journal of Animal Science*, 66, 385-395.

Du, M., & McCormick, R.J. *Applied Muscle Biology and Meat Science.* Taylor & Francis Group, LLC. 2009.

Fernandez, X., Monin, G., Talmant A., Mourot, J., & Lebret B. (1999) Influence of intramuscular fat content on the quality of pig meat- 2. Consumer acceptability of *m. longissimus lumborum*. *Journal of Meat Science*, 53, 67-72.

Font-i-Furnols, M., Tous, N., Esteve-Garcia, E., & Gispert, M. (2012). Do all consumers accept marbling the same way? The relationship between eating and visual acceptability of pork with different intramuscular fat content. *Meat Science*, 91, 448-453.

Forrest, J.C. (1998) Line speed implementation of various pork quality measures. NSIF conferences.

Fortomaris P., Arsenos G., Gerogiadis M., Banos G., Stamataris C., Zygoyiannis D (2006). Effect of Meat Appearance on Consumer Preferences for Pork Chops in Greece and Cyprus. *Meat Science*, 72, 688-696.

Gajana, C.S., Nkukwana, T.T., Marume, U., & Muchenje, V. (2013). Effects of transportation time, distance, stocking density, temperature and lairage time on incidences of pale soft exudative (PSE) and the physico-chemical characteristics of pork. *Meat Science*, *95*, 520-525.

Gooding, J.P., Holmer, S.F., Carr, S.N., Rincker, P.J., Carr, T.R., Brewer, M.S., McKeith, F.K., & Killefer, J. (2009). Characterization of striping in fresh, enhanced pork loins. *Meat Science,* 81, 364-371.

Grandin, T. (2000). Methods to reduce PSE and bloodsplash. Veterinary Outreach Programs, University of Minnesota, 21, 206-209.

Grunert, K.G., Bredahl, L. & Brunso, K. (2004). Consumer perception of meat quality and implications for product development in the meat sector- a review. *Meat Science*, 66, 259-272.

Hedrick, H.B., Aberle E.D., Forrest J.C., Judge M.D., & Merkel R.A. *Principles of Meat Science Third Edition*. 1989.

Holmer, S.F., McKeith, R.O., Boler, D.D., Dilger, A.C., Eggert, J.M., Petry, D.B., McKeith, F.K., Jones, K.I., & Killefer, J. (2009). The effect of pH on shelf-life of pork during aging and simulated retail display. *Meat Science*, 82, 86-93.

Huff-Lonergan, E., Baas, T.J., Malek, M., Dekkers, J. C., Prusa K., & Rothschild, M.F. (2002). Correlations among selected pork quality traits. *Journal of Animal Science, 80*(3), 617-627.

Huff-Lonergan, E., & Page, J. (2002). The Role of Carcass Chilling in the Development of Pork Quality. Fact Sheet: Pork Information Gateway. National Pork Board and American Meat Science Association Fact Sheet.

Hughes, J.M., Oiseth, S.K., Purslow, P.P., & Warner, R.D. (2014). A structural approach to understanding the interactions between colour, water-holding capacity and tenderness. *Meat Science*, *98*, 520-532.

Jeremiah, L.E. (2001). Marbling and pork tenderness. Fact Sheet. National Pork Board. Des Moines, IA.

Jones, S.D.M., Robertson, W.M., & Talbot, S. (1992). Marbling standards in beef and pork. Agriculture and Agri-Food Canada Publication Number 1879/E, Ottawa, ON.

Kauffman, R.G., Cassens, R.C., Scherer A., & Meeker, D.L. (1992). Variations in pork quality. National Pork Producers Council publication, Des Moines, IA.

Koohmaraie, M. (1996). Biochemical factors regulating the toughening and tenderization process of meat. *Meat Science*, 43, 193-201.

Koohmaraie, M., Kent, M.P., Shackelford, S.D., Veiseth, E., & Wheeler, T.L. (2002). Meat tenderness and muscle growth is there any relationship? *Meat Science*, 62, 345-352.

Koohmaraie, M., & Geesink, G.H. (2006). Contribution of postmortem muscle biochemistry to the delivery of consistent meat quality with particular focus on the calpain system. *Meat Science*, 74, 34-43.

Lesiow, T., & Xiong, Y.L. (2013). A simple, reliable and reproductive method to obtain experimental pale, soft and exudative (PSE) pork. *Meat Science*, 93, 489-494.

Lonergan S. (2008). Pork Quality: pH decline and pork quality. Fact Sheet. National Pork Board.

Mancini R.A., & Hunt M.C. (2005). Current research in meat color. *Meat Science*, 71, 100-121.

Mabry, J.W., & Baas, T.J. (1998). The impacts of genetics on pork quality (revised). Fact Sheet. National Pork Board and American Meat Science Association.

Marriott N.G., & Schilling M.W. (2006). Utilization of pale, soft, and exudative pork. Fact Sheet. National Pork Board.

McEwen, P., & Mandell, I. (2011). A literature review on the effects of moisture enhancement on pork quality. August 30th, 2011. Accessed September 8, 2014.

McMullen, L.K. (2005). Consumer preference, attitude, and acceptance of pork. *Animal Industry Report*: AS 652, ASL R2164.

Meisinger, D. (2008). A system for assuring pork quality. National Pork Board.

Miller, R.K. (2002). Functionality of non-meat ingredients used in enhanced pork. Fact Sheet. National Pork Board/American Meat Science Association.

Moeller, S.J., Miller, R.K., Zerby, H.N., Edwards, K., Logan, K.E., & Boggess, C.A. (2009). Effects of pork loin quality and enhancement on consumer acceptability and cooking characteristics of pork loin chops. 62nd Annual Reciprocal Meat Conference.

Moeller, S.J., Miller, R.K., Edwards, K.K., Zerby, H.N., Logan, K.E., Aldredge, T.L., Stahl, C.A., Boggess, M., & Box-Steffensmeier, J.M. (2010a). Consumer perceptions of pork eating quality as affected by pork quality attributes and end-point cooked temperature. *Meat Science*, 84, 14-22.

Moeller, S.J., Miller, R.K., Aldredge, T.L., Logan, K.E., Edwards, K.K., Zerby, H.N., Boggess, M., Box-Steffensmeier, J.M., & Stahl, C.A. (2010b). Trained sensory perception of pork eating quality as affected by fresh and cooked pork quality attributes and end-point cooked temperature. *Meat Science*, 85, 96-103.

Monin G. (1998). Recent methods for predicting quality of whole meat. *Meat Science, 49*, S231-S243.

National Pork Board. (2012). Grocery shopper intercepts: Pork purchasing decision factors.

Newman, D.J. (2012). National pork retail benchmarking study. Des Moines, IA. National Pork Board. Available from http://research.pork.org/Results/ResearchDetail.aspx?id=1760. Accessed September 8, 2014.

Nold, Rosie. University of Nebraska. Meat Quality Fact Sheet.

Ngapo T.M., Martin J.F., & Dransfield E. (2007). International preference for pork appearance: II. Factors influencing consumer choice. *Journal of Food Quality and Preference*, 18, 139-151.

Norman, M.G., & Schilling W.M. (2002) Utilization of Pale, Soft, and Exudative Pork. Fact Sheet. National Pork Board/ American Meat Science Association.

Norman, J.L., Berg, E.P., Heymann, H., & Lorenzen, C.L. (2003). Pork loin color relative to sensory and instrumental tenderness and consumer acceptance. *Meat Science*, 65, 927-933.

NPB (National Pork Board). (2000). "Other White Meat" ranked in top five of nation's most recognizable ad slogans. (Press release). Available from: http://www.porkboard.org/News/NewsEdit.asp?NewsID=200. Accessed September 8, 2014.

NPB (National Pork Board). (2011). Official color & marbling quality standards. Des Moines, IA: National Pork Board.

NPB (National Pork Board). (2014). Checkoff unveils its 2020 strategic plan. Available from: http://www.pork.org/checkoff-reports/new-tool-cuts-online-auditing-maze/checkoff-unveils-2020-strategic-plan/. Accessed January 11, 2015.

NPPC Usage Study. (1993). In: Brewer, M.S., 1998. Consumer attitudes toward color and marbling of fresh pork. National Pork Board "Pork Facts" (1998).

NPPC (National Pork Producers Council). (1999). Pork quality standards. Des Moines, IA: National Pork Producers Council.

NPPC (National Pork Producers Council). (2000). Pork composition and quality assessment procedures. National Pork Producers Council. Des Moines, IA.

O'Neill, D.J., Lynch, P.B., Troy, D.J., Buckley, D.J., & Kerry, J.P. (2003). Influence of the time of year on the incidence of PSE and DFD in Irish pigmeat. *Meat Science*, 64, 105-111.

Papanagiotou P., Tzimitra-Kalogianni I., Melfou K. (2013). Consumers' expected quality and intention to purchase high quality pork meat. *Meat Science*, 93, 449-454.

Pearson, R.C., McKenna, D.R., Ellebracht, J.W., Griffin, D.B., McKeith, F.K., Scanga, J.A., Belk, K.E., Smith, G.C., & Savell, J.W. (2005a). Benchmarking value in the pork supply chain: processing and consumer characteristics of hams manufactured from different quality raw materials. *Meat Science*, 70, 91-97.

Pearson, R.C., McKenna, D.R., Griffin, D.B., McKeith, F.K., Scanga, J.A., Belk, K.E., Smith, G.C., & Savell, J.W. (2005b). Benchmarking value in the pork supply chain: processing characteristics and consumer evaluations of pork bellies of different thickness when manufactured into bacon. *Meat Science*, 70, 121-131.

Pig Improvement Company (PIC) Technical Update. Meat Quality: Understanding Industry Measurements and Guidelines. (2003).

Prestat, C., Jensen, J., McKeith, F.K. & Brewer, M.S. (2002). Cooking method and endpoint temperature effects on sensory and color characteristics of pumped pork loin chops. *Meat Science*, 60, 395-400.

Reicks, A.L., Brooks, J.C., Kelly, J.M., Kuecker, K., Boillot, W.G., Irion, R., & Miller, M.F. (2008). National meat case study 2004: product labeling information, branding, and packaging trends. *Journal of Animal Science*, 86, 3593-3599.

Rosenvold K., Andersen H.J. (2003). Factors of significance for pork quality- a review. *Meat Science*, 64, 219-237.

Scheffler, T.L., & Gerrard, D.E. (2007). Mechanisms controlling pork quality development: The biochemistry controlling postmortem energy metabolism. *Meat Science*, 77, 7-16.

Shackelford, S.D., Wheeler, T.L., & Koohmaraie, M. (1999b). Evaluation of slice shear force as an objective method of assessing beef longissimus tenderness. *Journal of Animal Science,* 77, 2593-2699.

Shackelford, S.D., Wheeler, T.L., & Koohmaraie, M. (2004a). Technical note: use of belt grill cookery and slice shear force for assessment of pork longissimus tenderness. *Journal of Animal Science*, 83, 238-241.

Sheard, P.R., Nute, G.R., Richardson, R.I., Perry, A., & Taylor, A.A. (1999). Injection of water and polyphosphate into pork to improve juiciness and tenderness after cooking. *Meat Science*, 51, 371-376.

Stagnito Media. (2013). 2013 Progressive Grocer's Marketing Guidebook. Print or online at www.marketingguidebook.com.

Stetzer, A.J., & McKeith, F.K. (2003). Benchmarking value in the pork supply chain: Quantitative strategies and opportunities to improve quality. Savoy, IL: American Meat Science Association.

Tan, F.J., Morgan, M.T., Ludas, L.I., Forrest, J.C., & Gerrard, D.E. (2000). Assessment of fresh pork color with color machine vision. *Journal of Animal Science*, 78, 3078-3085.

Tapp III, W.N., Yancey, J.W.S., & Apple, J.K. (2011). How is the instrumental color of meat measured? *Meat Science*, 89, 1-5.

USDA (United States Department of Agriculture). Barbecue and Food Safety. (2013). Available from: http://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food- safety-fact-sheets/safe-food-handling/barbecue-and-food-safety/CT Index. Accessed January 11, 2015.

Wheeler, T.L., Koohmaraie, M., Cundiff, L.V., & Dikeman M.E. (1994). Effects of cooking and shearing methodology on variation in Warner-Bratzler shear force values in beef. *Journal of Animal Science*, 72, 2325-2330.

Wheeler, T.L., Shackelford, S.D., & Koohmaraie, M. (1996). Sampling, cooking, and coring effects on Warner-Bratzler shear force values in beef. *Journal of Animal Science*, 74, 1553-1562.

Wheeler, T.L., Shackelford, S.D., & Koohmaraie, M. (2000). Variation in proteolysis, sarcomere length, collagen context, and tenderness among major pork muscles. *Journal of Animal Science*, 78, 958-965.

Wright, L.I., Scanga, J.A., Belk, K.E., Engle, T.E., Tatum, J.D., Person, R.C., McKenna, D.R., Griffin, D.B., McKeith, F.K., Savell, J.W., & Smith, G.C. (2005). Benchmarking Value in the Pork Supply Chain: Characterization of US Pork in the Retail Marketplace. *Meat Science*, 71, 451-463.

CHAPTER 2. NATIONAL PORK RETAIL BENCHMARKING STUDY: CENTER-CUT LOIN CHOP, SIRLOIN CHOP, AND BLADE STEAK ANALYSIS

Abstract

The objective of this benchmarking study was to quantify pork quality variation in the retail self-serve meat case throughout the United States from the top 3 major retailers in each city. One hundred forty-three retail supermarkets representing 29 cities from 23 states were chosen for sampling. An experienced grader analyzed subjective color (n= 3795) and marbling scores (n= 3795) and various quality defects on center-cut loin chops in package under store lighting. Only center-cut loin chops were analyzed for subjective color and marbling scores (2.85 ± 0.79, and 2.30 ± 1.07, respectively) in the retail stores. Ten packages of each brand and enhancement type [enhanced (EN) and non-enhanced (NON)] of center-cut loin chops, sirloin chops, and blade steaks were purchased. Subjective mean color values were evaluated in the laboratory on center- cut loin chops (2.74 ± 0.79), sirloin chops (3.04 ± 0.71), and blade steaks (4.76 ± 0.92). Enhanced center-cut loin chops evaluated in the laboratory had significantly higher mean subjective color scores (darker in color) than NON center-cut loin chops (2.73 vs. 2.66, $P < 0.0001$). Mean subjective marbling values evaluated in laboratory were 2.27 (± 1.02) for center-cut loin chops, 1.96 (± 0.79) for sirloin chops, and 2.91 (± 0.95) for blade steaks. Minolta L* mean values were 55.56 (± 3.63) for center-cut loin chops, 52.46 (± 3.58) for sirloin chops, and 45.84 (± 3.29) for blade steaks. Enhanced center-cut loin chops (54.46 vs. 55.99, $P < 0.0001$), and blade steaks (45.81 vs. 45.96, $P = 0.37$) had lower Minolta L* values then NON (respectively). Mean pH values were 5.83 (± 0.32) for center-cut loin chops, 5.90 (± 0.30) for sirloin chops, and 6.28 (± 0.33) for blade steaks. Enhanced product had significantly higher pH then NON; center-cut loin chops (6.00 vs. 5.74, $P < 0.0001$), sirloin chops (6.00 vs. 5.89, $P +$ 0.04), and blade steaks (6.42 vs. 6.28, $P = 0.04$). Mean Warner-Bratzler Shear Force (WBSF)

values were 24.25 N (± 7.23) for center-cut loin chops, 20.80 N (± 6.71) for sirloin chops, and 17.41 N (± 4.78) for blade steaks. Blade steaks had the lowest mean Minolta L* value (darkest in color), greatest mean pH value, and lowest WBSF (more tender) value compared to center-cut loin chops and sirloin chops. For all product categories, EN pork significantly had greater pH values than NON. Results indicate that a great deal of pork quality variation exists in the retail self-serve meat case nationwide, regardless of enhancement type.

Materials and Methods

Retail Store Selection and Sampling

North Dakota State University, The Ohio State University, and The University of Florida collaborated to benchmark pork quality according to the 2013 Progressive Grocer Marketing Guidebook (Stagnito Media, 2013). The Progressive Grocer Marketing Guidebook did not include club stores, however for the purpose of this study, club stores were included in the study. Cities sampled were identified from 7 different market regions (Table 2.1). Retail stores within each city were selected based on the following criteria: 1) Geographic population distribution and major retailers, both national and regional. 2) Top 3 retail supermarkets in each city. 3) Retail stores where middle class income consumers most frequently purchase pork.

One hundred and thirty-three retail supermarkets, representing 29 cities from across 23 states were selected for the study (Table 2.2). From each University there was a principal investigator assisted by a trained group of technical staff students. Three months prior to data collection, each principal investigator and the National Pork Board Retail Marketing Team met in Chicago, Illinois for a training session to plan, organize and discuss the data collection process, and to determine which specific stores and store locations within market regions would be visited for the study.

Table 2.1. Identification of cities included in retail store sampling by region.

	Region[1]						
	EC	MA	NE	PA	SE	SW	WC
Cities	Columbus	New York City	Boston	Los Angeles	Atlanta	Dallas	Chicago
	Detroit	Philadelphia	Hartford	Phoenix	Charlotte	Houston	Denver
	Indianapolis			Portland	Memphis	San Antonio	Des Moines
	Pittsburgh			Salt Lake City	Miami		Kansas City
				San Francisco	Tampa		Milwaukee
				Seattle			Minneapolis
							St. Louis

[1] EC = East Central; MA = Mid-Atlantic; NE = New England; PA = Pacific; SE = Southeast; SW = Southwest; WC = West Central

Table 2.2. Center-cut loin chop, sirloin chop, and blade steak demographics by region across the United States.

	Region[1]							National
	EC	MA	NE	PA	SE	SW	WC	
Center-Cut Loin Chops								
Cities included	4	2	2	6	5	2	7	28
Stores assessed	19	12	12	29	22	11	38	143
Brands assessed	8	10	11	18	14	9	14	84
Packages Observed[2]								
Enhanced	76	23	10	90	47	31	150	427
Non-enhanced	150	112	116	216	139	76	219	1,028
Packages Purchased[3]								
Enhanced	76	23	10	90	47	31	150	427
Non-enhanced	150	115	93	217	178	76	251	1,080
Sirloin Chops								
Cities included	1	1	2	6	4	1	5	20
Stores assessed	2	1	7	16	8	5	12	51
Brands assessed	1	1	5	9	5	3	7	31
Packages Purchased[3]								
Enhanced	11	0	6	25	0	2	34	78
Non-enhanced	0	3	26	53	40	8	25	155
Blade Steaks								
Cities included	1	0	2	6	5	2	5	21
Stores assessed	1	0	2	13	13	5	16	50
Brands assessed	1	0	2	7	7	4	7	28
Packages Purchased[3]								
Enhanced	5	0	0	19	9	3	20	56
Non-enhanced	0	0	4	43	44	12	67	170

[1] EC = East Central; MA = Mid-Atlantic; NE = New England; PA = Pacific; SE = Southeast; SW = Southwest; WC = West Central

[2] Number of packages of center-cut loin chops used for subjective, in-store assessment.

[3] Number of packages of center-cut loin chops purchased for instrumental assessment at North Dakota State University.

Boneless and bone-in center-cut loin chop, sirloin chop and blade steak samples were collected between January 2015 and April 2015 to eliminate any holiday or seasonal merchandizing variation. Retail supermarkets were visited between the hours of 09:00 A.M. and 17:00 P.M. In-store data collection parameters included:

1.) Store Information- date store was visited; store name and store identification number; address; state; zip; investigators; time store entered; time collection ended; linear footage in full and self-serve meat case for coffin, tiers and number of tiers; promotional items present for any pork, beef, poultry, other or none; stand up displays present for any pork, beef, poultry, other or none; cooking brochures for any pork, beef, poultry, other or none; coupons for any pork, beef, poultry, other or none; type of lighting (white LED, pink LED, or Florescent); three light (lumens) for tired and coffin display cases; compliance with pork nomenclature

2.) Self-Serve Pork Case Assessment: brand/packer; specific item description (nomenclature); cut (loin, sirloin, blade); bone-in or boneless; chop or roast; number of packages available; number of pieces per package; packaging type (modified atmosphere packaging, vacuum packaging, overwrap packaging); establishment number, product thickness (1,2, or 3); original price per pound; product label claims; recipe (sticker, price label, none); temperature recommendation (sticker, price label, none); temperature; sell-by-date; packed-on date, enhanced (yes or no); enhancement percent

3.) Package Quality Assessment: brand; packer; cut (loin, sirloin, blade); bone-in or boneless; package #; chop letter; color score (1-6); marbling (0-10); sell-by-date; blood splash; bruised; bone dust; purchased. Only center-cut loin chop (n= 3795) packages were randomly selected from the retail self-serve meat case and assessed under store lighting by an experienced grader for subjective color (NPB 1-6, 2011), and subjective marbling (NPB 1-10, 2011), and any pork quality defects including blood splash; bruised; bone dust.

In-Store Subjective Assessment

Subjective color score (NPB, 2011) under store lighting (1= pale, pinkish gray, to white to 6= dark, purplish red) was assessed on 10 randomly selected boneless and bone-in center-cut loin chop packages for each brand and enhancement type [enhanced (EN) or non-enhanced (NON)] by an experienced grader in the self-serve meat case. Subjective marbling score (NPB,

2011) under store lighting (1= practically devoid of marbling to 10= abundant of marbling) was assessed on 10 randomly selected boneless and bone-in center-cut loin chop packages for each brand and enhancement type [enhanced (EN) or non-enhanced (NON)] by an experienced grader in the self-serve meat case. Each center-cut loin chop was randomly selected for evaluation for both subjective color and marbling scores must have had at least 50% of lean muscle exposed in each package. The random selection for center-cut loin chops preference was given to boneless, 2.54-cm-thick center-cut loin chops. However, due to regional differences in pork availability, bone-in center-cut loin chops and/or the closest thickness for center-cut loin chop samples were also used for analysis as the situation depended necessary. When available, 10 packages containing a minimum of at least two center-cut loin chop, sirloin chop, and blade steak packages were purchased for each brand or enhancement type [enhanced (EN) or non-enhanced (NON)]. Sirloin chop and blade steak packages must have had at least 50% of lean muscle exposed in each package. Each of the 10 individual packages purchased were labeled one through 10. Depending on the number of center-cut loin chops available per package. Each center-cut loin chop that was analyzed received a letter (A to D) for record purposes. Once purchased, center-cut loin chop, sirloin chop, and blade steak packages were placed in either a Yeti Cooler or hard plastic cooler with reusable frozen ice packs. Coolers were shipped priority overnight to North Dakota State University (NDSU) for further subjective and instrumental measurements in the laboratory as described below.

In-Laboratory Subjective Measurements

Once coolers arrived at NDSU for in-laboratory assessment, arrival time and three internal cooler temperatures (top, middle, and bottom) were recorded. Additionally, all package information was re-recorded. Each package type was opened. Each center-cut loin chop, sirloin chop, and blade steak was placed on a foodservice tray and designated a center-cut loin chop, sirloin chop, or blade steak number. The center-cut loin chops, sirloin chops, and blade steaks were allowed a minimum 15 minute "bloom time". After bloom, an experienced grader assessed each center-cut loin chop, sirloin chop, and blade steak for subjective color score according to the National Pork Board Color Standards (NPB, 2011) under controlled lighting. After determining color score, the experienced grader assessed the same center-cut loin chops, sirloin chops, and blade steaks for subjective marbling score according to the National Pork Board Marbling Standards (NPB, 2011) under controlled lighting in the laboratory.

Instrumental Color Measurement

After subjective analysis, instrumental color (*CIE* L*, a*, and b* color space values) was measured using a Minolta Colorimeter (CR-300, 8 mm diameter head, 10° standard observer, C light source; (Minolta Company, Ramsey, NJ), and calibrated to a white tile with Yxy data (Y = 94.8, x = 0.3131, y = 0.3191). The Minolta head was firmly placed in the center of the *Longissimus* muscle of the center-cut loin chop, *Gluteus medius* muscle of the sirloin chop and *Serratus ventralis* muscle of the blade steak on the surface of the meat to record the L*, a*, and b* color space values.

pH Measurement

A minimum of one randomly selected center-cut loin chop, sirloin chop, and blade steak from each package was used to obtain pH values. Center-cut loin chop, sirloin chop, and blade steak pH was acquired using a portable pH meter (HI 98240; Hanna Instruments, Italy) equipped with a glass tipped pH probe (FC232D; Hanna Instruments, Italy) and calibrated to pH 7.01 and 4.01 in two different buffer solutions. The probe was inserted directly into the middle of the *Longissimus* muscle of the center-cut loin chop, *Gluteus medius* muscle of the sirloin chop and

Serratus ventralis muscle of the blade steak parallel to the cut surface. The pH probe was recalibrated after every 10 center-cut loin chops, sirloin chops, and blade steaks.

Warner-Bratzler Shear Force and Cook-Loss Percentage Measurements

Each center-cut loin chop, sirloin chop, and blade steak that was analyzed for subjective color, subjective marbling, and instrumental color was also selected for measuring tenderness using the Warner-Bratzler Shear Force (WBSF) method. Each center-cut loin chop, sirloin chop, and blade steak along with its chop identification number was individually placed in a vacuum package bag, was sealed and frozen at -20°C until thawed for WBSF measurement. Center-cut loin chops, sirloin chops, and blade steaks were thawed in the vacuum sealed package 24 hours in a cooler at 4°C. Once completely thawed, samples were removed from the vacuum sealed package and placed on a silver foodservice tray. Internal temperature was obtained using a large bore needle (14 g needle; Hamilton 7749-05 8" PTA N714). Each chop or steak had a copper-constantan insulated wire (Neoflon PFA) inserted into the geometric center of the *Longissimus* muscle of the center-cut loin chop, *Gluteus medius* muscle of the sirloin chop and *Serratus ventralis* muscle of the blade steak for each pork sample. Each cut was weighed prior to cooking ("on" weight) using a digital electronic weighing scale (model AND EK-300i; A&D Company Limited, Tokyo, Japan). The thermocouple was inserted into a hand-held Omega handheld digital thermometer (model HH801B; Omega Engineering, Inc., Stanford, CT) to determine "on" temperature. Before placing the cut onto the clam-style cooker (George Foreman Grill), the grill was preheated for approximately 10 minutes to 350°F (176.7°C) and the "on" time was recorded. All samples were placed on the grill with both cooking plates on both the top and bottom touching the lean surface. All samples were cooked until reaching an internal temperature of 65°C (149°F) then immediately removed from the grill. An "off" temperature and end time were recorded. Cooked samples were then placed back on a different foodservice tray. Five minutes after removal from the grill the samples were re-weighed to determine the cook-loss percentage. The samples were cooled for approximately 4 hours or to approximately 22.2°C prior to WBSF analysis. Six, 1.27-cm diameter cores parallel to the longitudinal orientation of the muscle fibers were removed from each cooked *Longissimus* muscle (center-cut loin chop), *Gluteus medius* muscle (sirloin chop), and the *Serratus ventralis* muscle (blade steak). All six cored samples were then sheared using the WBSF device (G-R Electrical Manufacturing Co., Manhattan, KA) perpendicular to the muscle fibers. Each of the six core samples were inserted and sheared between the 1.168 cm Warner-Bratzler stainless steel blade at a head speed of 200 mm/min used with a 9.072-kg load cell to segment cores. The maximum force for each of the six cores were recorded in kg and later were converted to Newton's from kg (1 kg= 9.80665002864 N).

Statistical Analysis

Data was analyzed using generalized least squares (PROC MIXED, SAS Institute, Cary, NC). Center-cut loin chops, sirloin chops, or blade steaks were the experimental unit. The model included enhancement type and the interaction between enhancement type and region as fixed effects and package within region, retailer, store, and brand as a random effect. Additionally, Pearson correlations (PROC CORR; SAS Institute, Cary, NC) were calculated across and within enhancement type to determine the relationship between Minolta color (L*. a*, and b*), pH, and WBSF.

Results and Discussion

Product Demographics

The number of packages observed and purchased in each product category for regional totals are further described in Table 2.2. Nationally, 29 cities were visited, one hundred forty-three retail stores were assessed, and 84 different brands were assessed. In-store 427 EN and 1,028 NON packages of center-cut loin chops were observed for subjective assessment of color and marbling scores. Instrumental in-laboratory assessment included 427 EN and 1,080 NON center-cut loin chop packages, 78 EN and 155 NON sirloin chop packages, and 56 EN and 170 NON blade steak purchased packages. McEwen and Mandall (2011) reported marketing of non-enhanced pork is expected to increase due to consumer's health concerns associated with consuming pork products that are enhanced with sodium and phosphates. Accordingly, from this present study, there were more available non-enhanced product for assessment and purchase. Regional differences in product availability were found for sirloin chops, by which the East Central (EC), Mid-Atlantic (MA), New England (NE) and South West (SW) regions offered a very constrained selection of sirloin chops. In contrast for sirloin chop packages, the Pacific (PA) and West Central (WC) regions had a much larger selection for purchase. Similarly, for blade steaks, the EC, MA, NE, SE, and SW regions offered very constrained selection of blade steaks. There were no blade steaks available in the MA region for EN product. Whereas, blade steaks were more readily available for purchase within the PA, SE, and WC regions.

Subjective Pork Quality Attributes

Center-cut loin chop packages were the only retail pork cut assessed in the store at the self-serve retail meat case. Table 2.3 presents the national representation of simple statistics of center-cut loin chops evaluated in-store and in-laboratory for subjective color and marbling score pork quality attributes. The mean subjective center-cut loin chop color score value observed in the store (n= 3795) was 2.85 (± 0.79) and mean subjective color score value observed in the laboratory (n= 5427) was 2.74 (± 0.79). The mean subjective in-store and in-laboratory subjective color scores reported from the present benchmarking study was lower than previous benchmarking studies.

Table 2.3. National representation of simple statistics of center-cut loin chop, sirloin chop, and blade steak quality attributes.

	n	Mean	Minimum	Maximum	SD	CV%
Center-cut loin chops						
Color[1]						
In-store	3795	2.85	1.00	5.00	0.79	27.75
In laboratory	5427	2.74	1.00	6.00	0.79	28.84
Marbling[2]						
In-store	3795	2.30	1.00	10.00	1.07	46.60
In laboratory	5427	2.27	1.00	10.00	1.02	45.03
L*[3]	5488	55.56	43.14	72.55	3.63	6.54
a*[4]	5493	16.60	4.35	27.47	2.30	13.86
b*[5]	5493	10.33	3.25	19.07	1.53	14.80
pH	2428	5.83	4.83	7.32	0.32	5.54
WBSF[6], N	3067	24.25	7.71	67.99	7.23	29.83
Sirloin chops						
Color[1]	636	3.04	1.00	5.00	0.71	23.26
Marbling[2]	647	1.96	0.00	6.00	0.79	40.50
L*[3]	345	52.46	41.36	61.84	3.58	6.83
a*[4]	346	17.34	10.08	25.94	2.59	14.96
b*[5]	346	9.79	4.94	13.71	1.77	18.11
pH	508	5.90	5.26	6.93	0.30	5.16
WBSF[6], N	423	20.80	7.71	50.18	6.71	32.26
Blade steaks						
Color[1]	483	4.76	2.00	6.00	0.92	19.28
Marbling[2]	487	2.91	0.00	6.00	0.95	32.65
L*[3]	470	45.84	37.82	56.97	3.29	7.17
a*[4]	470	18.97	12.18	28.76	2.13	11.22
b*[5]	470	7.92	2.61	12.38	1.76	22.17
pH	441	6.28	5.02	7.12	0.33	5.24
WBSF[6], N	391	17.41	6.51	39.46	4.78	27.45

[1] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011). Sirloins and blade steaks were only evaluated for subjective color in the laboratory.
[2] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011). Sirloins and blade steaks were only evaluated for subjective marbling in the laboratory.
[3] Lightness scale: 0 = black; 100 = white.
[4] Redness scale: < 0 = green; > 0 = red.
[5] Yellowness scale: < 0 = blue; > 0 = yellow.
[6] WBSF = Warner-Bratzler shear force.

In the ‘2002 Benchmarking Value in the Pork Supply Chain’ study Wright et al. (2005) observed a mean subjective color score of 3.52 (± 0.85) in boneless loin chops in the retail meat case. Moeller et al. (2010a) reported a mean color score of 3.13 (± 1.04) in pork loins. In the ‘2012 National Retail Pork Quality Benchmarking’ study Newman (2012) reported a subjective color score of 3.12 (± 0.85) in center-cut loin chops. In-store subjective marbling was 2.30 (± 1.07) and in-laboratory the mean subjective marbling was 2.27 (± 1.02) (Table 2.3). The mean in-store and in-laboratory subjective marbling scores reported from the present study were slightly lower than the marbling scores 2.37 (± 0.86) in boneless loin chops observed by Wright et al. (2005), 2.43 (± 1.27) in pork loins observed by Moeller et al. (2010a), and 2.48 (± 0.95) in center-cut loin chops observed by Newman (2012). Overall, subjective color and marbling results from the present ‘2015 National Pork Retail Benchmarking’ study is inconsistent when compared with the results observed by Wright et al. (2005), Moeller et al. (2010b), and Newman (2012). Comparisons of subjective color and marbling and other pork quality parameters to the ‘2012 National Pork Retail Benchmarking’ study (Newman, 2012) will be described in further detail in the proceeding chapter.

Consumer acceptability of fresh pork color and marbling at the retail level have been shown in other literature. Brewer et al. (2001c) reported higher marbled chops were lighter pink in color (2.42 ± 0.94) than low and medium marbled chops. They suggest this was due to the mixture of white intramuscular fat and pink color from myoglobin and caused more light reflection on the cut surface which influenced the score assessed by the those evaluating subjective color. The lower subjective color and marbling scores in the present study suggest that modern consumers are left with lower quality pork at the retail meat case.

With regards to EN and NON center-cut loin chops, EN had a higher (darker) mean in-store subjective color score than NON (3.07 vs. 2.74, $P < 0.0001$). Likewise, EN had a higher (darker color) mean subjective color score (2.73 vs. 2.66, $P < 0.0001$) (Table 2.4) in lab, suggesting EN center-cut loin chops appeared darker under store lighting and under controlled lighting than NON counterparts. NON center-cut loin chop subjective marbling score was greater (2.02 vs. 2.32, $P < 0.0001$) than EN. Likewise, in-laboratory NON had a higher marbling score (2.09 vs. 2.31, $P < 0.0001$) than EN.

Noteworthy in the present study, the interaction of enhancement type by region were observed for subjective color and marbling scores for center-cut loin chops, sirloin chops, and blade steaks (Table 2.5). The interaction between enhancement types by region may be due to different distributors or companies represented in that region or the amount of EN and NON product available for purchase. The purpose of this study was to quantify variation in pork quality parameters in the retail meat case and not recognize the different packers or companies which supply pork to the specific regions. Therefore, discussion of the interactions will focus on the variation and differences due to enhancement across regions for subjective color and marbling. The SW region significantly had a greater in-store subjective color score (darker color) for EN center-cut loin chops than for NON (3.61 vs. 2.78, $P < 0.05$), with no differences observed ($P > 0.36$) in the other 6 regions. Subjective marbling score in-store was significantly lower for EN center-cut loin chops in the SE (1.66 vs 2.44, $P < 0.05$) and WC (1.86 vs 2.38, $P < 0.05$) regions but did not differ ($P > 0.33$) in other regions. There were no differences observed for the interaction of enhancement type by region for subjective color or marbling for sirloin chops or for blade steaks. The enhancement type by region interactions for subjective color and marbling are not simply explained, but are not likely due to observer bias as experienced graders obtained information in multiple regions.

Table 2.4. Least square means (S.E.) of enhanced (EN) and non-enhanced (NON) center-cut loin chop, sirloin chop, and blade steak quality attributes nationwide.

	EN	NON	P-value
Center-cut loin chops			
Color[1]			
In-store evaluation	3.07 (0.06)	2.74 (0.02)	< .0001
In laboratory evaluation	2.73 (0.06)	2.66 (0.02)	< .0001
Marbling[2]			
In-store evaluation	2.02 (0.08)	2.32 (0.03)	< .0001
In laboratory evaluation	2.09 (0.07)	2.31 (0.03)	< .0001
L*[3]	54.46 (0.26)	56.00 (0.10)	< .0001
a*[4]	16.19 (0.15)	16.00 (0.06)	0.26
b*[5]	9.59 (0.11)	10.38 (0.04)	< .0001
pH	6.00 (0.02)	5.74 (0.01)	< .0001
WBSF[6], N	20.43 (0.50)	25.99 (0.19)	< .0001
Sirloin chops			
Color[1]	3.04 (0.11)	3.12 (0.08)	0.57
Marbling[2]	1.97 (0.12)	1.97 (0.08)	0.99
L*[3]	53.74 (0.83)	52.51 (0.49)	0.20
a*[4]	17.30 (0.53)	16.24 (0.31)	0.09
b*[5]	10.21 (0.40)	9.66 (0.23)	0.24
pH	6.00 (0.05)	5.89 (0.03)	0.04
WBSF[6], N	16.18 (1.04)	22.92 (0.67)	< 0.0001
Blade steaks			
Color[1]	4.73 (0.15)	4.72 (0.18)	0.96
Marbling[2]	3.06 (0.17)	2.87 (0.11)	0.37
L*[3]	45.81 (0.56)	45.96 (0.38)	0.82
a*[4]	19.04 (0.38)	17.84 (0.26)	0.01
b*[5]	8.18 (0.30)	7.65 (0.20)	0.14
pH	6.42 (0.05)	6.28 (0.05)	0.04
WBSF[6], N	15.74 (0.75)	19.42 (0.71)	0.0005

[1] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011). Sirloins and blade steaks were only evaluated for subjective color in the laboratory.
[2] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011). Sirloins and blade steaks were only evaluated for subjective marbling in the laboratory.
[3] Lightness scale: 0 = black; 100 = white.
[4] Redness scale: < 0 = green; > 0 = red.
[5] Yellowness scale: < 0 = blue; > 0 = yellow.
[6] WBSF = Warner-Bratzler shear force.

Table 2.5. Least squares means (S.E.) per region of enhanced (EN) and non-enhanced (NON) center-cut loin chop quality attributes.

	Region[1]														*P*-values	
	EC		MA		NE		PA		SE		SW		WC			
	EN	NON	EN	NON	EN	NON	EN	NON	EN	NON	EN	NON	EN	NON	E	R*E
Center-cut loin chops																
Color[2]																
In-store[2]	2.69 (0.13)	2.63 (0.06)		2.32 (0.06)	2.90 (0.22)	2.62 (0.07)	2.86 (0.08)	2.79 (0.05)	3.37 (0.13)	3.01 (0.06)	3.61a (0.15)	2.78b (0.08)	3.00 (0.07)	3.00 (0.05)	< 0.0001	< 0.0001
In-laboratory[2]	2.84 (0.13)	2.65 (0.06)		2.54 (0.07)	1.86 (0.23)	2.42 (0.08)	2.76 (0.09)	2.68 (0.05)	3.12 (0.13)	2.71 (0.05)	2.95 (0.15)	2.72 (0.08)	2.84 (0.07)	2.90 (0.05)	0.2843	< 0.0001
Marbling[3]																
In-store[3]	1.76 (0.18)	2.28 (0.08)		2.18 (0.09)	2.30 (0.31)	2.51 (0.10)	2.52 (0.12)	2.43 (0.07)	1.66a (0.18)	2.44b (0.08)	2.04 (0.21)	2.04 (0.11)	1.86a (0.10)	2.38b (0.07)	0.0005	< 0.0001
In-laboratory[3]	2.00 (0.15)	2.21 (0.07)		2.19 (0.08)	1.58 (0.28)	2.44 (0.09)	2.43 (0.11)	2.34 (0.06)	2.05 (0.16)	2.41 (0.06)	2.51 (0.18)	2.41 (0.10)	1.94 (0.09)	2.15 (0.06)	0.0045	0.0001
L*[4]	53.55a (0.56)	55.91b (0.26)		56.69 (0.28)	57.82 (1.02)	56.37 (0.31)	55.44 (0.39)	55.85 (0.22)	52.23a (0.58)	56.36b (0.24)	52.44a (0.67)	55.23b (0.36)	55.28 (0.33)	55.58 (0.23)	< 0.0001	< 0.0001
a*[5]	14.90a (0.33)	16.31b (0.15)		15.10 (0.17)	14.86 (0.60)	14.79 (0.19)	15.97 (0.23)	16.03 (0.13)	16.26 (0.34)	17.17 (0.14)	16.18 (0.39)	15.60 (0.21)	18.96a (0.19)	17.03b (0.14)	0.2622	< 0.0001
b*[6]	9.21a (0.23)	10.57b (0.11)		10.28 (0.12)	10.97 (0.43)	9.89 (0.13)	9.73a (0.16)	10.42b (0.09)	8.77a (0.24)	10.89b (0.10)	8.80a (0.28)	10.15b (0.15)	10.08 (0.14)	10.43 (0.10)	< 0.0001	< 0.0001
pH	5.66 (0.04)	5.72 (0.02)		5.65 (0.02)	5.71 (0.08)	5.73 (0.02)	5.96a (0.03)	5.79b (0.02)	6.33a (0.05)	5.70b (0.02)	6.36a (0.05)	5.84b (0.03)	5.98a (0.03)	5.76b (0.01)	< 0.0001	< 0.0001
WBSF[7], N	23.69 (0.97)	26.86 (0.48)		27.09 (0.60)	25.23 (2.10)	25.08 (0.57)	18.80a (0.68)	25.82b (0.36)	17.80a (1.08)	25.58b (0.43)	18.23a (1.36)	25.74b (0.62)	18.86a (0.60)	25.73b (0.43)	< 0.0001	< 0.0001
Sirloin chops																
Color[2]	3.01 (0.19)			4.00 (0.35)	2.50 (0.26)	2.70 (0.17)	3.27 (0.15)	2.98 (0.10)		3.03 (0.10)	3.17 (0.43)	3.24 (0.21)	3.24 (0.12)	2.77 (0.19)	0.5655	0.0118
Marbling[3]	1.74 (0.19)			2.04 (0.35)	1.83 (0.26)	2.20 (0.15)	2.35 (0.15)	1.96 (0.10)		1.86 (0.10)	2.33 (0.44)	2.16 (0.21)	1.60 (0.12)	1.59 (0.20)	0.9875	0.0049
L*[4]	54.42 (1.01)			49.45 (1.82)	55.78 (2.06)	55.82 (1.12)	53.16 (0.82)	52.48 (0.64)		51.79 (0.59)	53.23 (3.28)	51.11 (1.35)	52.12 (0.74)	54.43 (1.21)	0.2036	0.0141
a*[5]	17.00 (0.65)			15.51 (1.17)	15.98 (1.32)	14.49 (0.69)	17.64 (0.53)	17.24 (0.41)		16.93 (0.38)	16.66 (2.11)	15.26 (0.87)	19.23 (0.47)	17.99 (0.77)	0.0873	0.0007
b*[6]	9.68 (0.48)			9.07 (0.86)	11.77 (1.01)	9.95 (0.51)	10.64 (0.39)	9.98 (0.31)		9.08 (0.28)	9.04 (1.57)	8.60 (0.65)	9.91 (0.35)	11.29 (0.58)	0.2384	0.0115
pH	5.49 (0.07)			5.93 (0.13)	5.80 (0.10)	5.75 (0.06)	5.98 (0.06)	5.91 (0.04)		5.79 (0.04)	6.64 (0.18)	6.09 (0.08)	6.07 (0.04)	5.80 (0.07)	0.0352	< 0.0001
WBSF[7], N	17.28 (1.60)			25.86 (2.82)	19.08 (2.35)	21.42 (1.27)	18.38a (1.24)	23.30b (0.79)		23.88 (0.78)	11.51 (4.08)	21.79 (1.82)	14.62a (0.94)	21.29b (1.47)	< 0.0001	0.1007
Blade steaks																
Color[2]	5.20 (0.34)					5.00 (0.86)	4.60 (0.20)	4.78 (0.12)	5.00 (0.45)	4.96 (0.11)	4.50 (0.45)	4.15 (0.22)	4.36 (0.18)	4.69 (0.12)	0.9581	0.0359

Table 2.5. Least squares means (S.E.) per region of enhanced (EN) and non-enhanced (NON) center-cut loin chop quality attributes (continued).

Marbling[3]	3.10 (0.38)	2.47 (0.46)	2.85 (0.22)	2.99 (0.14)	3.67 (0.50)	2.83 (0.13)	2.50 (0.50)	3.25 (0.25)	3.17 (0.20)	2.80 (0.13)	0.3677	0.4198
L*[4]	44.03 (1.26)	47.10 (1.52)	47.54a (0.73)	44.76b (0.46)	44.75 (1.63)	46.47 (0.42)	45.65 (1.63)	46.73 (0.82)	47.06c (0.65)	44.73d (0.44)	0.8222	0.0060
a*[5]	17.90 (0.86)	15.01 (1.04)	20.25 (0.50)	18.52 (0.31)	17.57 (1.11)	18.52 (0.29)	17.73 (1.11)	17.96 (0.56)	21.76a (0.45)	19.19b (0.30)	0.0102	< 0.0001
b*[6]	7.48 (0.67)	6.58 (0.80)	9.40a (0.39)	6.98b (0.24)	7.15 (0.86)	7.91 (0.22)	7.87 (0.86)	9.09 (0.43)	9.01c (0.34)	7.71d (0.23)	0.1423	0.0001
pH	5.67 (0.12)	6.34 (0.21)	6.54a (0.07)	6.21b (0.04)	6.87a (0.15)	6.29b (0.04)	6.70 (0.15)	6.21 (0.08)	6.34 (0.06)	6.33 (0.04)	0.0367	< 0.0001
WBSF[7], N	15.93 (1.70)	20.01 (3.18)	15.69c (0.98)	19.17d (0.64)	16.36 (2.19)	18.06 (0.57)	15.75 (2.19)	22.74 (1.18)	14.98 (0.88)	17.11 (0.59)	0.0005	0.0101

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.

[2] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011).0.0001. Sirloins and blade steaks were only evaluated for subjective color in the laboratory.

[3] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011). Sirloins and blade steaks were only evaluated for subjective marbling in the laboratory.

[4] Lightness scale: 0 = black; 100 = white.

[5] Redness scale: < 0 = green; > 0 = red.

[6] Yellowness scale: < 0 = blue; > 0 = yellow.

[7] WBSF = Warner-Bratzler shear force.

[a, b] Least square means with a, b in the same region differ by $P < 0.05$.

[c, d] Least square means with c, d in the same region differ by $0.05 < P < 0.10$.

Sirloin chops and blade steaks subjective color and marbling scores were only evaluated in-laboratory. The mean subjective color score was 3.04 (± 0.71) for sirloin chops and 4.73 (± 0.92) for blade steaks (Table 2.3.). The sirloin chop mean subjective color score was slightly lower than the 3.52 (± 0.85) observed by Wright et al. (2005), 3.13 (± 1.04) observed by Moeller et al. (2010a), and 3.12 (± 0.85) observed by Newman (2012). However, the blade steak mean subjective color score was much greater than the 3.52 (± 0.85) observed by Wright et al. (2005), 3.13 (± 1.04) observed by Moeller et al. (2010a), and 3.12 (± 0.85) observed by Newman (2012). Sirloin chop, and blade steak subjective marbling scores were 1.96 (± 0.79) and 2.91 (± 0.95), respectively. The sirloin chop mean subjective marbling score was lower than the 2.37 (± 0.86) observed by Wright et al. (2005), 2.43 (± 1.27) observed by Moeller et al. (2010a), and 2.48 (± 0.95) observed by Newman (2012). In comparison, the blade steak mean subjective marbling score was greater than the 2.37 (± 0.86) observed by Wright et al. (2005), 2.43 (± 1.27) observed by Moeller et al. (2010a), and 2.48 (± 0.95) observed by Newman (2012). Overall, blade steaks had greater subjective color and marbling scores than both center-cut loin chops and sirloin chops.

Least square means for enhanced (EN) and non-enhanced (NON) sirloin chops and blade steaks are presented in Table 2.4. EN sirloin chops had a higher subjective color score than NON (3.04 vs. 3.12, $P = 0.57$) indicating NON sirloin chops were lighter in color than EN chops. EN and NON sirloin chops had the same subjective marbling score of 1.97 ($P = 0.99$). EN blade steaks had a similar subjective color score than NON (4.73 vs 4.72, $P = 0.96$). EN blade steaks had a higher subjective marbling score than NON blade steaks (3.06 vs 2.87, $P = 0.37$). Regardless of enhancement type, blade steaks had greater subjective color and marbling scores than both center-cut loin chops and sirloin chops.

Instrumental Pork Quality Attributes

The simple statistics for center-cut loin chop, sirloin chop, and blade steak quality attributes of purchased pork are presented in Table 2.3. From the present study, blade steaks were darker in color (< L*) and had the most red (> a*) when compared to the other cuts. Contrary, center-cut loin chops were lighter (> L*) and had the least red (< a*). Additionally, blade steaks had the greatest pH value, while center-cut loin chops and sirloin chops had similar pH values (5.83 and 5.90, respectively). Warner-Bratzler Shear Force mean values for blade steaks and sirloin chops were less (more tender) then center-cut loin chops (more tough). Profiling pork muscle reports (Porcine Myology) exhibit that the *Longissimus* muscle of center-cut loin chops has a lesser proportion of Type I (red muscle fibers) compared to Type IIB (white muscle fibers), where the *Serratus ventralis* muscle of the blade steak has a larger proportion of Type I muscle fiber types. These would suggest the *Serratus ventralis* muscle exhibits a lower L* value, a greater a* and greater pH when compared to the other two cuts.

EN center-cut loin chops were significantly darker (lower Minolta L* value) than NON (54.46 vs 56.00, P < 0.0001). The results could be due to that enhancing pork with non-meat ingredients results in a greater pH so less proteins are denatured, causing less water-loss and ultimately less water on the cut surface; reflecting less light. EN sirloin chops had a slightly higher Minolta L* value than NON (53.74 vs. 52.51, P = 0.20) indicating EN sirloin chops were lighter in color than NON chops. EN blade steaks Minolta L* were closely similar between EN and NON (45.81 vs. 45.96, P = 0.86). Therefore, the results explain EN blade steals were darker in color compared to NON. EN sirloin chops had a Minolta a* color space value significantly greater than NON counter parts (17.30 vs. 16.24, P = 0.09), concluding EN blade steaks were more red then NON. Similar to sirloin chops, EN blade steaks had a Minolta a* value significantly greater than NON blade steaks (19.04 vs. 17.84, *P* = 0.01).

Results for the mean pH values for center-cut loin chops, sirloin chops, and blade steaks are presented in Table 2.3. The least square means for enhanced (EN) and non-enhanced (EN) for center-cut loin chops, sirloin chops and blade steaks pH values are presented in Table 2.4. EN center-cut loin chops significantly had a higher pH value than NON (6.00 vs 5.74, $P < 0.0001$). EN sirloin chops significantly had a higher pH value than NON (6.00 vs. 5.89, $P = 0.04$). EN blade steaks significantly had a higher pH than NON (6.42 vs. 6.28, $P = 0.04$). As anticipated, enhancing pork significantly increases the pH value for all product categories. This is consistent with the observed lower L* values of EN center-cut loin chops and blade steaks. One justification for the higher pH value in EN product is due to the addition of non-meat ingredients. Miller (2002) reported the addition of water, sodium, or phosphates increased the pH that allows proteins to bind more free water which results in less moisture on the cut surface, and less light reflection that allows for a darker appearance. Retailers therefore have the option to present darker pork to consumers by enhancing pork.

For tenderness using the Warner-Bratzler Shear Force (WBSF) method, the mean values were 24.25 N (± 7.23) for center-cut loin chops, 20.80 N (± 6.71) for sirloin chops, and 17.41 N (± 4.78) for blade steaks (Table 2.3). EN center-cut loin chops were significantly more tender (lower WBSF value) than NON (20.43 vs. 25.99, $P < 0.0001$). EN sirloin chops were significantly more tender (lower WBSF value) than NON (16.18 vs. 22.92 N, $P < 0.0001$). EN blade steaks were significantly more tender (lower WBSF value) than NON (15.74 vs. 19.42 N, $P = 0.0005$). NON center-cut loin chops had a mean WBSF value lower than what Moeller et al. (2010b) reported with a consumer sensory panel that favored pork with a WBSF value less than

24.5 N. All other cuts and enhancement type, except for NON center-cut loin chops can be classified nationwide as tender.

The effect of enhancement type [enhanced (EN) and non-enhanced (NON)] (Table 2.4.) and the interaction of enhancement type [enhanced (EN) and non-enhanced (NON)] by region (Table 2.5.) on pork quality were dependent on product cut and region. The Minolta L* value for EN center-cut loin chops was significantly lower (darker color) in the SW (52.2 vs. 52.4, $P < 0.05$) and SW (52.4 vs. 55.2, $P < 0.05$) regions but no differences were observed ($P > 0.98$) in the other regions. There were no differences for Minolta L* value for EN and NON sirloin chops in any of the regions. The Minolta L* value for NON blade steaks was significantly lower (darker color) in the PA (47.5 vs. 44.76, $P < 0.05$) region than NON blade steaks. Also, NON blade steaks had a tendency to have a lower Minolta L* in the WC (47.1 vs. 44.7, $0.05 < P < 0.10$) region than EN, but no differences were observed ($P > 0.99$) in the other regions. The Minolta a* value for EN center-cut loin chops was significantly higher (more red) in the WC (19.0 vs. 17.0, $P < 0.05$) region than NON, but no differences were observed ($P > 0.41$) in the other regions. Likewise, the Minolta a* value for EN blade steaks were significantly higher (more red) in the WC (21.8 vs. 19.2, $P < 0.05$) region than NON, but no differences were observed ($P > 0.11$) in the other regions. For Minolta b*, NON center-cut loin chops significantly had a higher Minolta b* value in the PA (9.7 vs. 10.4, $P < 0.05$), SE (8.8 vs. 10.9, $P < 0.05$), and SW (8.8 vs. 10.2, $P < 0.05$) regions than EN, but no differences were observed ($P > 0.43$) in the other regions. While, EN blade steaks significantly had a higher Minolta b* value (more yellow) in the PA (9.4 vs. 6.9, $P < 0.05$) region, and EN blade steaks had a tendency difference to have a higher Minolta b* in the WC (9.0 vs. 7.7, $0.05 < P < 0.10$) region than NON, but no differences were observed ($P > 0.96$) in the other regions. Many of the regions had significant differences in pH for enhancement type. EN center-cut loin chops significantly had a higher pH value in the PA (6.0 vs. 5.8, $P < 0.05$), SE (6.3 vs. 5.7, $P < 0.05$), SW (6.4 vs. 5.8, $P < 0.05$), and WC (6.0 vs. 5.8, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.99$) in the other regions. While, EN blade steaks significantly had a higher pH value in the PA (6.5 vs. 6.2, $P < 0.05$) and SE (6.9 vs. 6.3, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.14$) in the other regions. A majority of the regions had significant differences in tenderness (WBSF) for enhancement type. EN center-cut loin chops significantly had a lower WBSF (more tender) value in the PA (18.8 vs. 25.8 N, $P < 0.05$), SE (17.8 vs. 25.6 N, $P < 0.05$), SW (18.2 vs. 25.7 N, $P < 0.05$), and WC (18.9 vs. 25.7 N, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.14$) in the other regions. EN sirloin chops significantly had a lower WBSF (more tender) value in the PA (18.4 vs. 23.3 N, $P < 0.05$) and WC (14.6 vs. 21.3 N, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.44$) in the other regions. EN blade steaks only had a tendency difference to have a lower WBSF in the PA (15.7 vs. 19.2 N, $0.05 < P < 0.10$) region than NON, but no differences were observed ($P > 0.14$) in the other regions. Overall, there were varying differences between the interaction of enhancement type and region from this present study.

Pork Quality Attributes Frequency Distributions

The distribution of subjective color score measured in-store of enhanced (EN) versus non-enhanced (NON) center-cut loin chops, sirloin chops, and blade steaks are presented in Figure 2.1. The mean subjective color score observed in the laboratory was 2.73 (± 0.06) for EN center-cut loin chops and 2.66 (± 0.02) for NON center-cut loin chops ($P < 0.0001$). Approximately half of all center-cut loin chops assessed had a subjective in-laboratory subjective color score of 3 (56.8 % for EN and 48.9 % for NON). The frequency distribution amongst the in-laboratory subjective color scores between EN and NON center-cut loin chops showed little difference. Norman et al. (2003) separated boneless pork loins into three different groups based on subjective color standards (NPB, 2011) and showed 20.8 % of consumers selected pork with a color score of 1 or 2, 26.4 % selected pork with a color score of 3 or 4 and approximately half of the consumers (52.8 %) selected pork with a color score of 5 or 6. In the current study, 31.0 % of EN and 36.5 % of NON center-cut loin chops had a color score of 1 or 2. Moreover, 1.0 % of EN and 0.9 % of NON center-cut loin chops had a color score of 5 or 6.

A subjective color score of 1 is described as being pale, pinkish gray to white and a subjective color score 2 is described as being grayish pink (NPB, 2011). While a subjective color score of 5 is described as being purplish red and a subjective color score 6 is described as dark, purplish red (NPB, 2011). It is important to note that a significant amount of pork loins in the U.S. are sorted in processing plants based on subjective color for export markets or other food-service sectors. Thus, this could be a significant reason for the lower amount of center-cut loin chops in the self-serve retail meat case with color scores of 5 or 6 and greater percentage of pale colored center-cut loin chops in the self-serve retail meat case. Similar to center-cut loin chops, sirloin chops had a majority of subjective color scores of 3 (64.8 % for EN and 53.3 % for NON). Which corresponds to the mean subjective color score for sirloin chops of 3.04 (± 0.11) for EN and 3.12 (± 0.08) for NON center-cut loin chops (P = 0.57). Only 11.4 % of EN and 24.2 % of NON sirloin chops had a color score of 1 or 2. There were no subjective color scores of 6 for either enhancement type, therefore 1.4 % of EN and 1.64 % of NON sirloin chops had a color score of 5 or 6. In contrast, blade steaks overall had 92.3 % of subjective color scores greater than 3. This is because the results indicate that the mean subjective color score of 4.73 (± 0.15) for EN and 4.72 (± 0.18) for NON blade steaks (P = 0.96). Only 15.5 % of EN and 4.7 % of

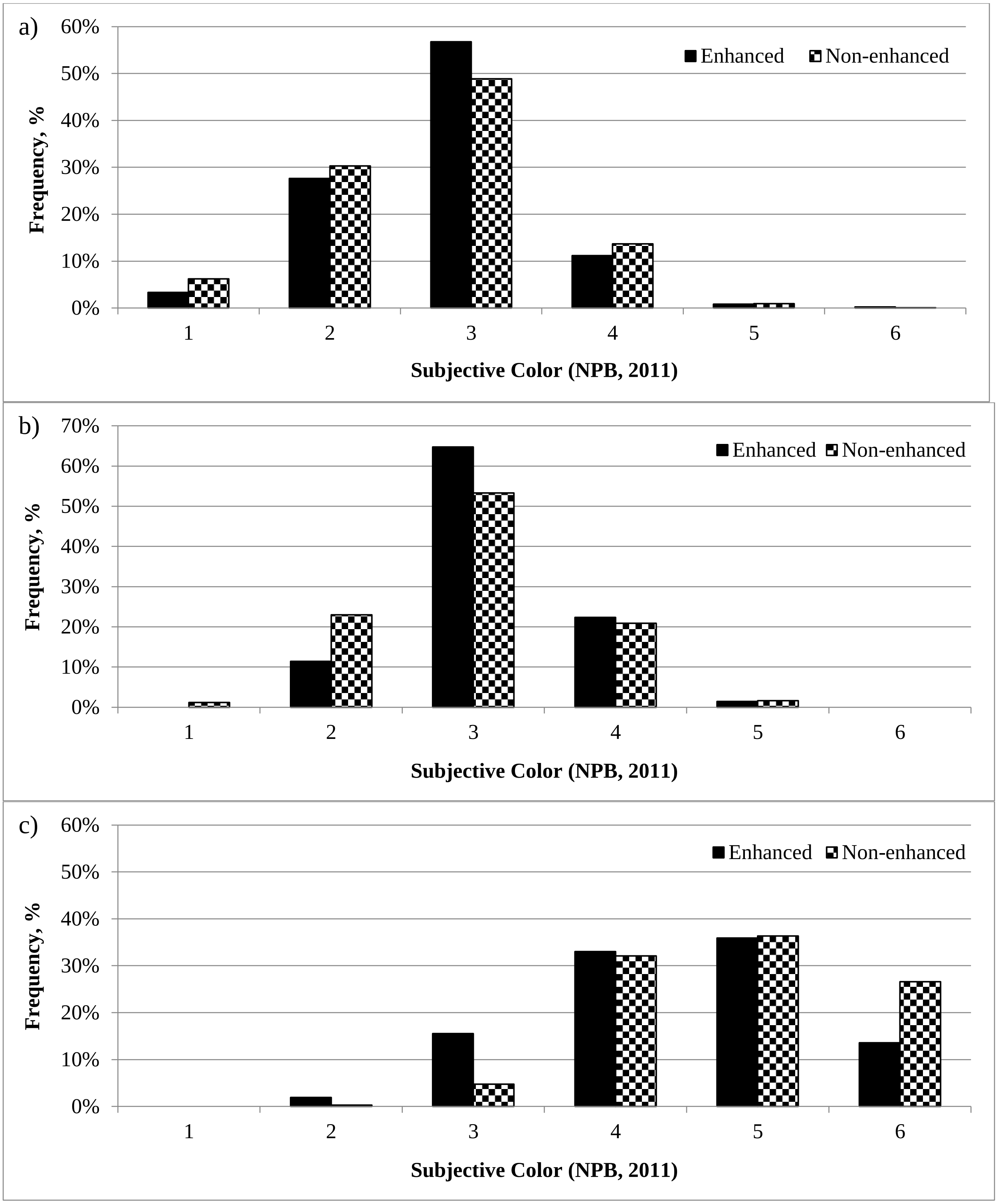

Figure 2.1. Frequency distribution of subjective color score measured in-laboratory of enhanced (EN) and non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks.

NON blade steaks had a subjective color score of 3. Whereas, 1.9 % of EN and 0.3 % of NON blade steaks had a subjective color score of 1 or 2. There were no subjective color scores of 1.

Furthermore, 49.5 % of EN and 62.9 % of NON blade steaks had a color score of 5 or 6. Therefore, based on the results, for the different product categories, there is not a color issue associated with sirloin chops or blade steaks, but is more of a concern in center-cut loin chops.

The mean subjective marbling score evaluated in the laboratory was 2.09 (± 0.07) for EN center-cut loin chops with 38.1 % scoring a 2 and 50.8 % scoring a 1 or 3 (25.9 % and 24.9 %, respectively) (Figure 2.2). The mean subjective marbling score evaluated in the laboratory was 2.31 (± 0.03) for NON center-cut loin chops, with 43.5 % scoring a 2 and 47.8 % scoring a 1 or 3 (18.8 % and 29.0 %, respectively). The mean subjective marbling score was 1.97 (± 0.12) for EN sirloin chops with 51.9 % scoring a 2 and 40.5 % scoring a 1 or 3 (28.1 % and 12.4 %, respectively). The mean subjective marbling score was also 1.97 (± 0.08) for NON sirloin chops with 51.5 % scoring a 2 and 46.2 % scoring a 1 or 3 (24.9 % and 21.3 %, respectively). The mean subjective marbling score was 3.06 (± 0.17) for EN blade steaks with only 19.4 % scoring a 2 and 50.5 % scoring a 1 or 3 (7.8 % and 42.7 %, respectively). EN blade steak distribution for a subjective marbling score of 4 was 28.2 %. The mean subjective marbling score was 2.87 (± 0.11) for NON blade steaks with 25.3 % scoring a 2 and 52.9 % scoring a 1 or 3 (5.5 % and 47.4 %, respectively). Cannata et al. (2012) reported when IMF was 2.5 % or greater tenderness and juiciness increased. Similarly, Fernandaz et al. (1999a) reported when IMF values reached 2.5 % juiciness and flavor was enhanced. Furthermore, Font-i-Furnols et al. (2012) recommended 2.2-3.4 % minimum of IMF improves eating satisfactoriness. Rincker et al. (2008) concluded nearly 50 % of consumers in a sensory panel selected pork loin chops in a case with the least amount of marbling, but said they would purchase pork that is leaner. Moeller et al. (2010) suggested IMF levels of 5-6 % would improve pork flavor, but contribute very little or have no influence on consumer’s perceptions of juiciness or tenderness attributes. Results from this current study, in comparison with past literature observing marbling pork quality sensory attributes, suggest that in the self-serve retail meat case nationwide, all cuts have marbling values that reinforce satisfactory eating quality, except for EN sirloin chops.

Minolta L* frequency distribution of enhanced (EN) and non-enhanced (NON) center-cut loin chops, sirloin chops, and blade steaks are presented in Figure 2.3. The mean EN and NON Minolta L* values were (54.46 vs. 56.00, $P < 0.0001$) for center-cut loin chops, (53.74 vs. 52.51, $P < 0.00001$) for sirloin chops, and (45.81 vs. 45.96, $P = 0.82$) for blade steaks. The mean Minolta L* value was 54.46 (± 0.26) for EN center-cut loin chops with 59.5 % of the chops were in the Minolta L* value range of 52.00 to 57.99, 24.9 % of the chops had a Minolta L* < 52.00 and 15.5 % had a Minolta L* > 58.00. The mean Minolta L* value was 56.00 (± 0.10) for NON center-cut loin chops with 58.7 % of the chops were in the Minolta L* value range of 52.00 to 57.99, 13.4 % of the chops had a Minolta L* < 52.00 and 28.0 % had a Minolta L* > 58.00. The instrumental color, Minolta L* values are based on Meisinger et al. (1999). The National Pork Board subjective color standards (NPB, 2011) for subjective color are provided with a reference to the Minolta L* values. For instance, a color score of 1 is characterized with a Minolta L* value of 58.00, while a color score of 6 is characterized to a Minolta L* value of < 34.00. Therefore, from the present study's results of a subjective in-store mean subjective color score of 3.07 EN and 2.74 NON and in-laboratory mean subjective color of 2.73 EN and 2.66 NON. This would represent a Minolta L* close to 51.58 for EN in-store subjective color, 53.56 for NON in-store subjective color 53.62 for EN in-laboratory subjective color, and 54.04 for NON in-laboratory subjective color, when compared to the NPB color standards. Yet, the mean Minolta L* values reported in the current study (54.46 for EN and 56.00 for NON) are analytic of a subjective color score of 2.59 for EN and 2.33 for NON center-cut loin chops.

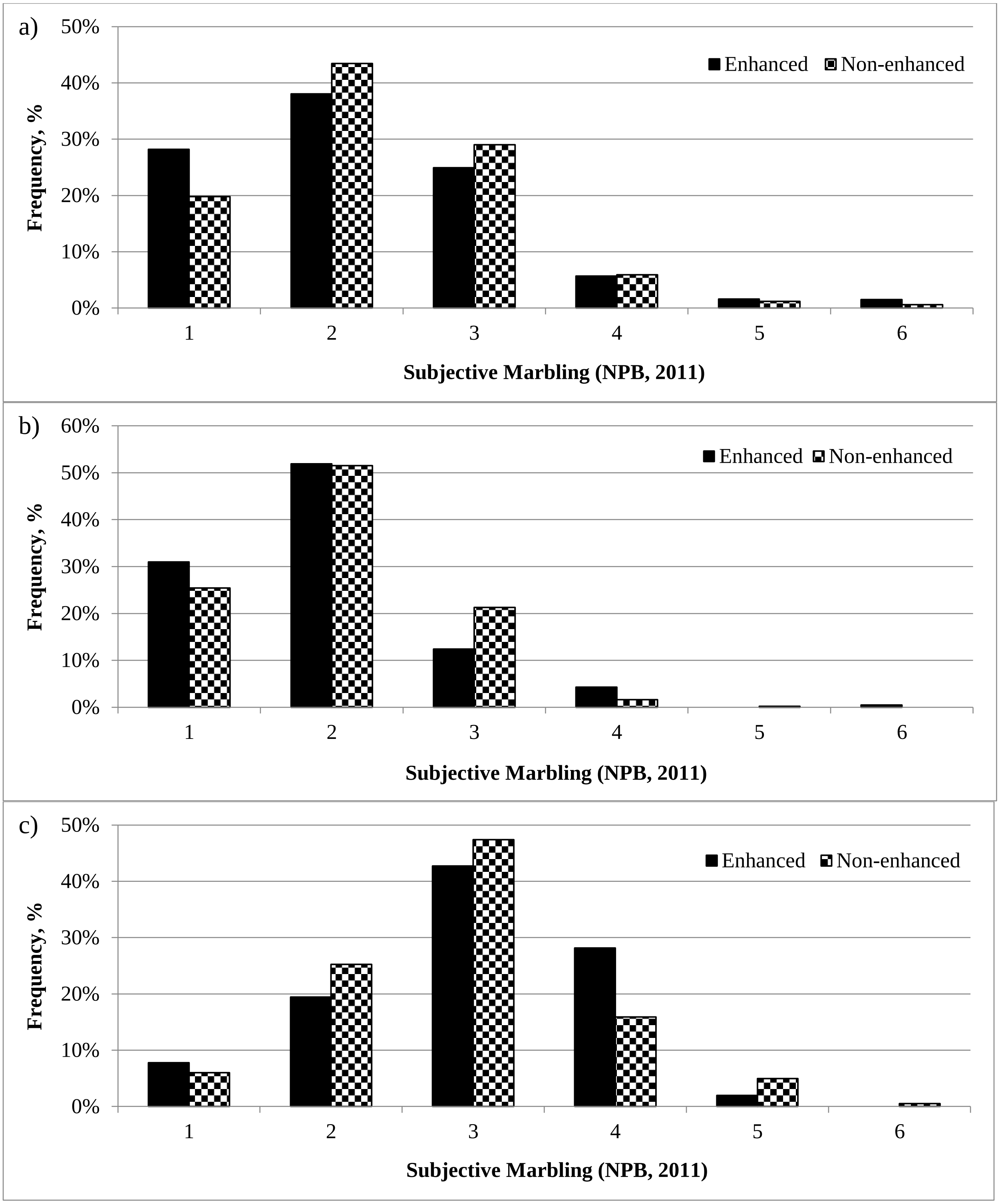

Figure 2.2. Frequency distribution of subjective marbling score measured in-laboratory of enhanced (EN) and non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks.

Therefore, experienced graders are reporting a subjective color score darker than the Minolta L* value. This could be due to the effect of different in-store lighting (fluorescent or white LED or pink LED) at different retail stores, as well as assessing subjective color scores under controlled lighting in-laboratory. The mean Minolta L* value was 53.74 (± 0.83) for EN sirloin chops, with 54.8 % of the chops were in the Minolta L* value range of 52.00 to 57.99, 41.5 % of the chops had a Minolta L* < 52.00, and 4.0 % had a Minolta L* > 58.00. The mean Minolta L* value was 52.51 (± 0.49) for NON sirloin chops, with 47.5 % of the chops were in the Minolta L* value range of 52.00 to 57.99, 45.3 % of the chops had a Minolta L* < 52.00, and 7.2 % had a Minolta L* > 58.00. The mean Minolta L* value was 45.81 (± 0.56) for EN blade steaks, with 7.1 % of the blade steaks were in the Minolta L* value range of 52.00 to 57.99, 92.9 % of the steaks had a Minolta L* < 52.00, and 0.0 % had a Minolta L* > 58.00. The mean Minolta L* value was 45.96 (± 0.38) for NON blade steaks, with 3.2 % of the steaks were in the Minolta L* value range of 52.00 to 57.99, 96.8 % of the chops had a Minolta L* < 52.00, and 0.0 % had a Minolta L* > 58.00. A possible explanation for the differences between subjective and instrumental color values is first, the type of light source different retailers use varies in the self-serve meat case. As well, subjective color evaluated in-store was assessed with the samples in package. Thus, based on the different light sources in-store, the fresh pork may appear darker or lighter to the experienced grader in-laboratory under controlled lighting. Additionally, in-laboratory, the fresh pork received a minimum of 15-minute bloom time to be exposed to oxygen.

Frequency distribution for pH of enhanced (EN) and non-enhanced (NON) center-cut loin chops, sirloin chops, and blade steaks are presented in Figure 2.4. Moeller et al. (2010a) indicated pork loins with an ultimate pH value between 5.8 and 6.4 had positive sensory

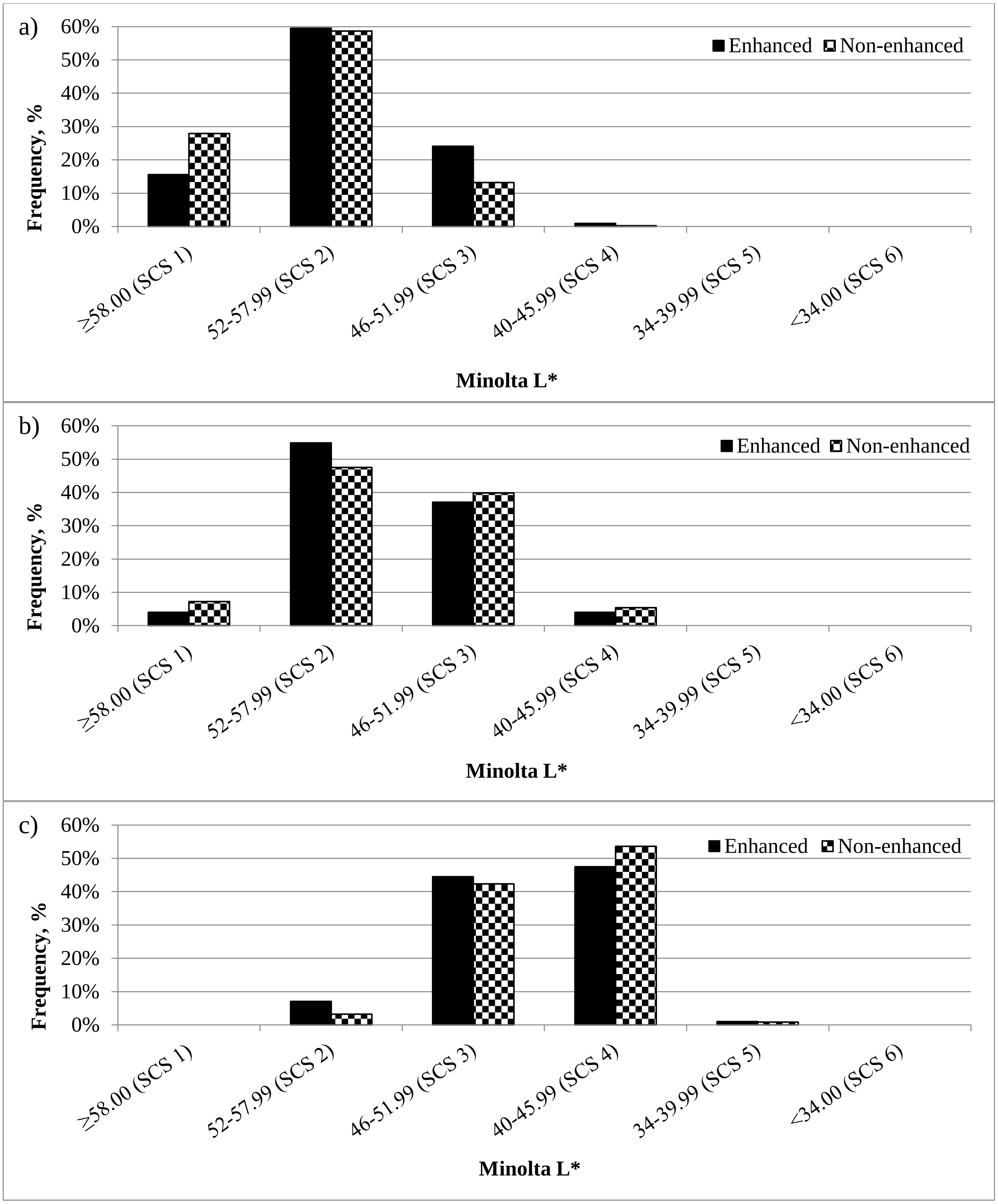

Figure 2.3. Minolta L* frequency distribution of enhanced (EN) versus non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks.

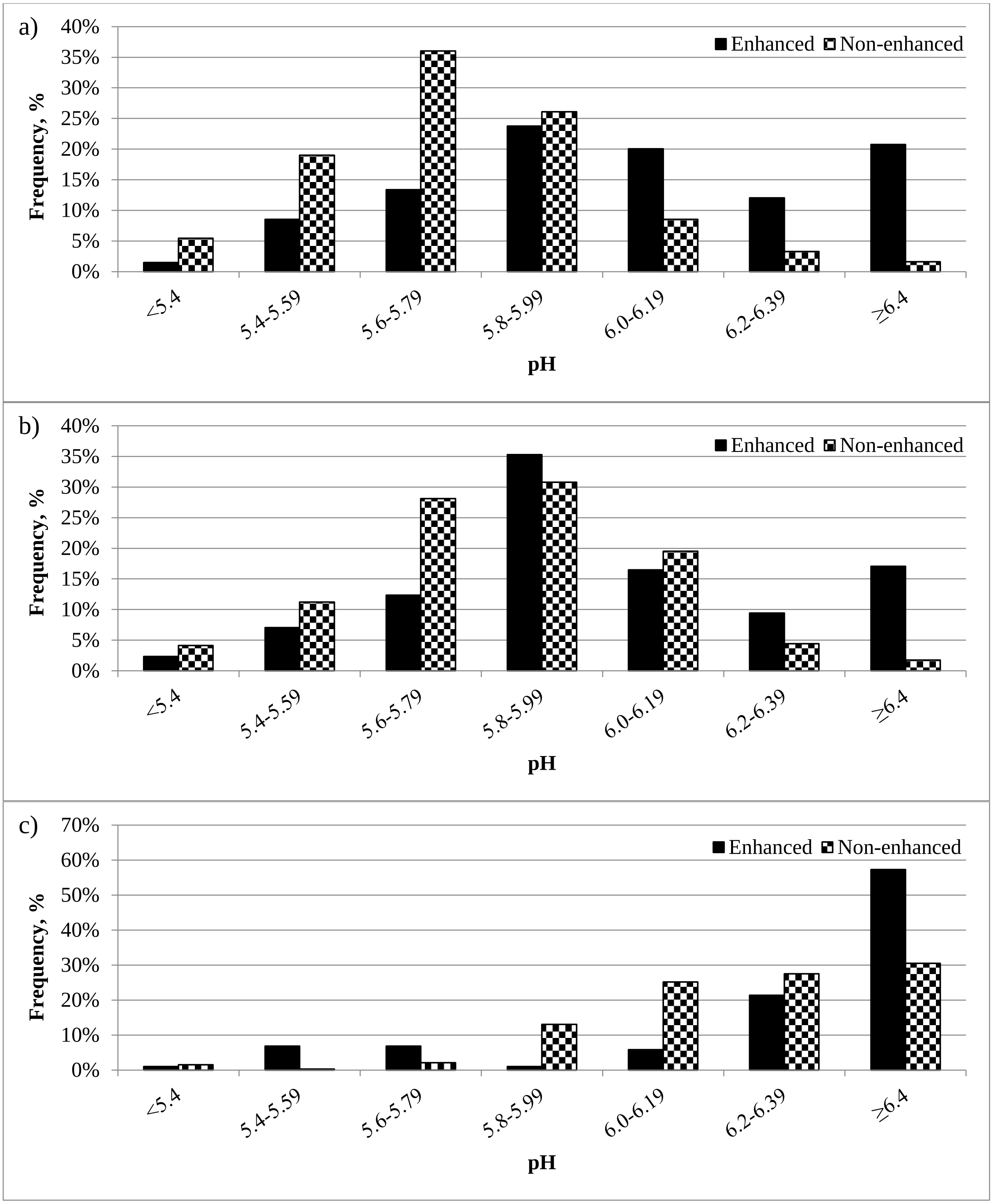

Figure 2.4. Frequency distribution for pH of enhanced (EN) versus non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steak.

responses from a trained panelist. For all cuts, enhanced product had a higher pH value than non-enhanced. The mean pH value was 6.00 (± 0.02) for EN center-cut loin chops, in which 42.4 %

of all center-cut loin chops and 55.9 % of EN center-cut loin chops had a pH value between 5.8 and 6.4. The mean pH value was 5.74 (± 0.01) for NON center-cut loin chops, in which 37.9 % of NON had a pH value between 5.8 and 6.4. While, 20.7 % of EN and 1.6 % NON of center-cut loin chops had a pH value greater than 6.4 and 23.4 % EN and 60.5 % NON center-cut loin chops had a pH value less than 5.8. The mean pH value was 6.00 (± 0.05) for EN sirloin chops in which 61.2 % had a pH value between 5.8 and 6.4. The mean pH value was 5.89 (± 0.03) for NON sirloin chops, in which approximately half (54.7 %) had a pH value between 5.8 and 6.4. While, 17.1 % of EN and 1.8 % of NON sirloin chops had a pH value greater than 6.4 and 21.8 % of EN and 43.5 % of NON sirloin chops had a pH value less than 5.8. The mean pH value was 6.42 (± 0.05) for EN blade steaks, in which 28.2 % had a pH value between 5.8 and 6.4. The mean pH value was 6.28 (± 0.05) for NON blade steaks, in which 65.7 % had a pH value between 5.8 and 6.4. While, 57.3 % of EN and 30.5 % NON had a pH value greater than 6.4 and 14.6 % of EN and 3.9 % of NON had a pH value less than 5.8. Overall, the average pH values for blade steaks were greater than center-cut loin chops and sirloin chops. Yet, previous research has mostly been conducted in loin chops and on the effect of pH on eating quality. Thus, the results determined in this present study of overall greater pH in blade steaks and the shift in proportion of samples within greater pH categories cannot be determined without sensory evaluation to support a conclusion of ideal pH for eating quality for consumers. One explanation for the differences in enhancement type for pH is the addition of non-meat ingredients to the pork at the plant to create an enhanced product for retailers. Miller (2002) reported the addition of water, sodium or phosphates increases the pH that allows proteins to bind more free water, and less moisture on the cut surface, resulting in less light reflection and in turn appears darker. Thus, retailers have the option to present darker pork to consumers by enhancing pork.

The percentage distribution for Warner-Bratzler Shear Force (WBSF) of enhanced (EN) and non-enhanced (NON) center-cut loin chops, sirloin chops, and blade steaks are presented in Figure 2.5. The mean WBSF value was 20.43 N (± 0.50) for EN center-cut loin chops, in which 23.5 % of the center-cut loin chops were in the WBSF range of 19.6 to 24.5 N, with 57.9 % being < 19.6 N and 18.5 % being > 24.5 N. The mean WBSF value was 25.99 N (± 0.19) for NON center-cut loin chops, in which 29.2% of the center-cut loin chops were in the WBSF range of 19.6 to 24.5 N, with 16.7 % being < 19.6 N and 54.1 % being > 24.5 N. The mean WBSF value was 16.18 N (± 1.04) for EN sirloin chops, in which 13.9 % of the sirloin chops were in the WBSF range of 19.6 to 24.5 N, with 6.15 % being < 19.6 N and 80.0% being > 24.5 N. The mean WBSF value was 22.92 N (± 0.67) for NON sirloin chops, in which 31.4 % of the sirloin chops were in the WBSF range of 19.6 to 24.5 N, with 6.2 % being < 19.6 N and 80.0 % being >24.5 N. The mean WBSF value was 15.74 N (± 0.75) for EN blade steaks, in which 6.8 % of the blade steaks were in the WBSF range of 19.6 to 24.5 N, with 4.9 % being < 19.6 N and 88.4% being > 24.5 N. The mean WBSF value was 19.42 N (± 0.71) for NON blade steaks, in which 24.7 % of the blade steaks were in the WBSF range of 19.6 to 24.5 N, with 8.0 % being < 19.6 N and 67.4 % being > 24.5 N.

Moeller et al. (2010b) determined consumers positively responded to WBSF values below 24.5 N, for tenderness-like, tenderness-level, juiciness-like, juiciness-level, and overall-like, but for every 4.9 N increase in WBSF value above 24.5 N, their overall-like decreased by 4%. From the present study for all cuts, 55.2 % of center-cut loin chops (81.4 % of EN and 45.9 % of NON), 73.3 % of sirloin chops (93.9 % of EN and 64.2 % of NON), and 92.8 % of blade steaks (95.1 % EN and 92.0 % of NON) can be classified as tender pork due to the distribution falling below the threshold of 24.5 N reported by Moeller et al. (2010b).

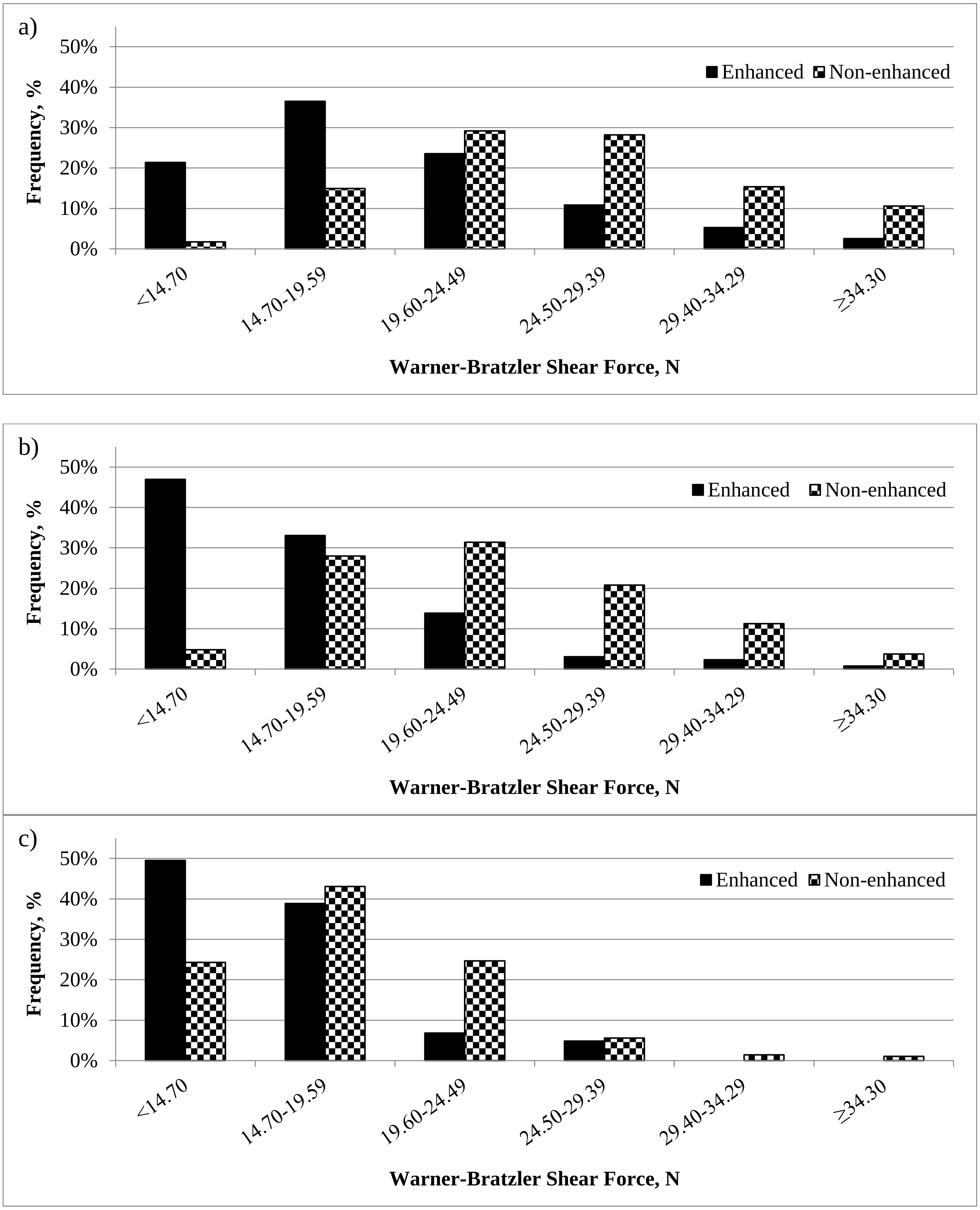

Figure 2.5. Frequency distribution for Warner-Bratzler Shear Force (WBSF) of enhanced (EN) and non-enhanced (NON) a) center-cut loin chops, b) sirloin chops, and c) blade steaks

Pork Quality Attributes Correlation Coefficients

Correlation coefficients of L*, a*, and b*, pH, and Warner-Bratzler Shear Force in center-cut loin chops, sirloin chops and blade steaks are presented in Table 2.6. Results indicate Minolta L* was moderately and negatively correlated with a* across all cuts and enhancement type, as well as moderately and negatively correlated with pH for all cuts and enhancement type, except for EN blade steaks. In contrast, Minolta L* was significantly strongly and positively correlated ($P < 0.05$) with b* regardless of enhancement type or cut evaluated in the present study. In blade steaks for all enhancement types, and NON center-cut loin chops, Minolta a* and b* were positively correlated. Norman et al. (2003) noted L* is negatively correlated with a* (r = -0.32) and in center-cut loin chops positively correlated (0.62) with b*. Additionally, a* and b* within center-cut loin chops are positively correlated (.40) (Norman et al., 2003), in which all results found agree with the present study. Minolta a* and WBSF were negatively correlated for all EN product in all cuts, and NON blade steaks. There was a positive correlation between a* and pH in sirloin chops and EN center-cut loin chops.

Table 2.6. Correlations of L*, a*, b*, pH, and Warner-Bratzler shear force (WBSF) in center-cut loin chops, sirloin chops, and blade steaks.

	Enhanced				Non-enhanced				Across enhancement type			
	a*	b*	pH	WBSF	a*	b*	pH	WBSF	a*	b*	pH	WBSF
Center-cut loin chops												
L*	-0.29**	0.64**	-0.44**	0.21**	-0.37**	0.62**	-0.31**	0.04†	-0.37**	0.64**	-0.38**	0.14**
a*		0.04	0.30**	-0.23**		0.22**	0.04	0.00		0.11**	0.22**	-0.15**
b*			-0.43**	0.23**			-0.29**	0.07**			-0.38**	0.17**
pH				-0.41**				-0.15**				-0.37**
Sirloin chops												
L*	-0.48**	0.72**	-0.41**	0.24*	-0.32**	0.73**	-0.46**	0.00	-0.34**	0.72**	-0.40**	0.04
a*		-0.16†	0.63**	-0.49**		0.05	0.23**	0.04		0.00	0.53**	-0.32**
b*			-0.32**	0.23*			-0.44**	0.19**			-0.32**	0.12†
pH				-0.44**				-0.29**				-0.40**
Blade steaks												
L*	-0.15	0.68**	0.02	0.30**	-0.23**	0.68**	-0.40**	0.22**	-0.15**	0.68**	-0.25**	0.19**
a*		0.25**	0.08	-0.23*		0.15**	0.05	-0.17**		0.23**	0.10*	-0.23**
b*			-0.08	0.23*			-0.37**	0.31**			-0.24**	0.21**
pH				-0.14				-0.26**				-0.25**

† denotes correlations with P < 0.10; * denotes correlations with P < 0.05; ** denotes correlations with P < 0.01.

Minolta b* was positively and moderately correlated with WBSF center-cut loin chops. As well as, Minolta b* had a negative correlation with pH for all cuts and enhancement type, except for EN blade steaks.

Conclusions

Thus, the data observed in-store under the retail self-serve lighting and in-laboratory under controlled lighting suggests there is a considerable amount of variation in the retail meat case. In the present study investigators reported in-laboratory center-cut loin chops (31.0 % of EN, and 36.5 % of NON), and sirloin chops (64.8 % for EN and 53.3 % for NON) had a majority of subjective color scores of 3. Whereas, 49.5 % of EN and 62.9 % of NON blade steaks had a color score of 5 or 6, and a lower distribution for subjective color score of 3. Blade steak results indicate that the pork industry is currently providing a desirable color score for blade steaks. Subjective color score for center-cut loin chops has decreased over the past ten years regardless if analyzed in-store under retail lighting or in-laboratory under controlled lighting (2.85 vs. 2.74, respectively) from when Wright et al. (2005) and Newman (2012) conducted subjective color score in the retail meat case. In contrast, for subjective marbling, values were fairly consistent between EN and NON regardless of product category. Instrumental Minolta L* color results indicate that there is a sizeable amount of variation as well. An L* value between 46.00-51.99 is indicative of a subjective color score 3, data from the present study suggest only 24.05 % of EN center-cut loin chops and 13.16 % of NON center-cut loin chops had an L* value represented in the range. A majority of L* values > 52.00 had a color score below 3 for center-cut loin chops (75.1 % for EN and 86.6% of NON), sirloin chops (58.9 % for EN and 54.8 % for NON), and blade steaks (7.1 % for EN and 3.23 % for NON). From this study there is a large inconsistency between the subjective and instrumental color, particularly in center-cut loin chops and sirloin chops. As expected, pH for EN was generally greater than NON for all cuts. Results indicate that for center-cut loin chops, overall 55.2 %, 81.4 % of EN and 45.9 % of NON, sirloin chops overall 73.3 %, 93.9 % of EN and 64.2 % of NON, and blade steaks overall 92.8 %, 95.2 % of EN and 92.0 % of NON, were tender (WBSF ≤ 24.5 N) and ultimately would provide consumers a positive eating experience based on results from Moeller et al. (2010) regardless of cut. From the results we can conclude that there is a wide range of variation in center-cut loin chops that exists in the self-serve retail meat case. Benchmarking pork quality is essential to quantify the variation to express quality attributes being represented at the retail meat case for producers, processors and other industry stakeholders to use as a tool to implement necessary changes to reduce the variation, increase consumer demand and help in meeting the NPB 2020 Strategic Plan goal of reducing color scores of 1 and 2 by 10% by the year 2020 (NPB, 2014).

Literature Cited

Barbut, S. (2001). Effect of illumination source on the appearance of fresh meat cuts. *Meat Science,* 59, 187-191.

Cannata, S., Engle, T.E., Moeller, S.J., Zerby, H.N., Radunz, A.E., Green, M.D., Baas, P.D., & Belk, K.E. (2010). Effect of visual marbling on sensory properties and quality traits in pork loin. *Meat Science,* 85, 428-434.

CIE (Commission Internationale de I'eclairage). (1978). Recommendations on uniform color spaces- color equations, psychometric color terms. Supp. No. 2 to EIC Publ. No. 15 (E-1.3L) 1971 (9TC-1-3), CIE, Paris, France.

Fernandez, X., Monin, G., Talmant A., Mourot, J., & Lebret B. (1999) Influence of intramuscular fat content on the quality of pig meat- 2. Consumer acceptability of *m. longissimus lumborum*. *Journal of Meat Science*, 53, 67-72.

Font-i-Furnols, M., N. Tous, E. Esteve-Garcia, and M. Gispert. (2012). Do all the consumers accept marbling in the same way? The relationship between eating and visual acceptability of pork with different intramuscular fat content. *Meat Science* 91, 448-453.

Meisinger, D. J. (2003). The national pork quality benchmarking study. In: Proc. 56th Am. Meat Sci. Assoc. Reciprocal Meat Conf., Columbia, MO.

Meisinger, D. J., F. McKeith, J. Forrest, M. Morgan, and S. Brewer. (1999). New NPPC color and marbling standards. In: Proc. 52nd American Meat Science Association Reciprocal Meat Conference. Stillwater, OK.

Miller, R. (2002). Functionality of non-meat ingredients used in enhanced pork. Fact Sheet National Pork Board/ American Meat Science Association.

Moeller, S. J., R. K. Miller, T. L. Aldredge, K. E. Logan, K. K. Edwards, H. N. Zerby, M. Boggess, J. M. Box-Steffensmeier, and C. A. Stahl. (2010a). Trained sensory perception of pork eating quality as affected by fresh and cooked pork quality attributes and end-point cooked temperature. *Meat Science*, 85, 96-103.

Moeller, S.J., Miller, R.K., Edwards, K.K., Zerby, H.N., Logan, K.E., Aldredge, T.L. Stahl, C.A., Boggess, M., & Box-Steffensmeier, J.M. (2010b). Consumer perceptions of pork eating quality as affected by pork quality attributes and end-point cooked temperature. *Meat Science*, 84, 14-22.

Newman, D.J. (2012). National pork retail benchmarking study. Des Moines, IA. National Pork Board. Available from http://research.pork.org/Results/ResearchDetail.aspx?id=1760. Accessed September 8, 2014.

Norman, J. L., E. P. Berg, H. Heymann, and C. L. Lorenzen. (2003). Pork loin color relative to sensory and instrumental tenderness and consumer acceptance. *Meat Science*, 65,927-933.

NPB (2011). Official color & marbling quality standards. Des Moines, IA: National Pork Board.

Rincker, P. J., J. Killefer, M. Ellis, M. S. Brewer, and F. K. McKeith. (2008). Intramuscular fat content has little influence on the eating quality of fresh pork loin chops. *Journal of Animal. Science*. 86:730-737.

University of Nebraska – Lincoln. 2005. Porcine Myology. http://porcine.unl.edu/porcine2005/pages/index.jsp. (Last accessed 03 August 2015).

Wright, L.I., Scanga, J.A., Belk, K.E., Engle, T.E., Tatum, J.D., Person, R.C., McKenna, D.R., Griffin, D.B., McKeith, F.K., Savell, J.W., & Smith, G.C. (2005). Benchmarking Value in the Pork Supply Chain: Characterization of US Pork in the Retail Marketplace. *Meat Science*, 71, 451-463.

CHAPTER 3. COMPARISON OF 2012 NATIONAL PORK RETAIL BENCHMARKING STUDY VERSUS 2015 NATIONAL PORK RETAIL BENCHMARKING STUDY

Abstract

The objective of this study was to use the collection method from the '2012 National Pork Retail Benchmarking Study' (Newman, 2012) for sampling randomly selected center-cut loin chops, sirloin chops, and blade steaks from the top major retail locations in the United States. The pork quality information collected from the present study was compared against the benchmarking values obtained from the '2012 National Pork Retail Benchmarking Study'. Product demographics for all product categories differed between the two years; more EN center-cut loin chops were purchased in 2012 then 2015 and less NON center-cut loin chops were purchased in 2012 then 2015. Center-cut loin chop means comparing 2012 versus 2015 were (3.12 vs. 2.85, respectively) for subjective color evaluated in-store, (2.48 vs. 2.30, respectively) for subjective marbling evaluated in-store, (55.30 vs. 55.56, respectively) for Minolta L*, (5.86 vs. 5.83, respectively) for pH, and (23.39 vs. 24.25 N, respectively) for Warner-Bratzler Shear Force (WBSF). Enhancement type [enhanced (EN) vs. non-enhanced (NON)] means for center-cut loin chops in 2012 were (3.25 vs. 3.17) for subjective color, (2.32, 2.50, $P < 0.001$) for subjective marbling, (54.06 vs. 56.06, $P < 0.001$) for Minolta L*, (5.81 vs. 6.18, $P = 0.05$) for Minolta a*, (3.61 vs. 3.75 $P = 0.17$) for Minolta b*, (5.96 vs. 5.77, $P < 0.001$) for pH, and WBSF (20.83 vs. 25.20 N, $P < 0.001$) for WBSF. While mean values for center-cut loin chops in 2015 were (3.07 vs. 2.74, $P < 0.0001$) for subjective color, (2.02 vs. 2.32, $P < 0.0001$) for subjective marbling, (54.46 vs. 55.99, $P < 0.0001$) for Minolta L*, (16.19 vs. 16.00 $P =0.26$) for Minolta a*, (9.59 vs. 10.38, $P < 0.0001$) for Minolta b*, (6.00 vs. 5.74, $P < 0.0001$) for pH, and (20.43 vs. 25.99 N, $P < 0.0001$) for WBSF. Based on the simple statistics for center-

cut loin chops, the 2012 study had greater subjective color score, subjective marbling score, lower Minolta L*, greater pH value and lower WBSF values then the 2015 study. Suggesting that in both years there is a wide spread of variation in the retail meat case. However, no pork quality attributes obtained in the present study have improved in the retail meat case.

2012 Materials and Methods

Retail Store Selection and Sampling

North Dakota State University, Texas A&M University, The University of Florida, The Pennsylvania State University, The Ohio State University, and California Polytechnic State University collaborated to benchmark pork quality from the top major retailers and supermarkets according to the 2011 Progressive Grocer Marketing Guidebook (Stagnito Media, 2011). One hundred seventeen retail stores representing 32 market areas were identified for sampling. Samples were collected between February 2012 and April 2012.

Ten center-cut loin chop packages for each brand and enhancement type [enhanced (EN) and non-enhanced (NON)] were randomly selected from the retail self-serve meat case. Packages were evaluated under store lighting for subjective color (NPB, 2011) (1= pale, grayish pink, white to 6= dark, purplish red) and subjective marbling (NPB, 2011) (1= practically devoid of marbling, to 10= abundant of marbling). Each center-cut loin chop was randomly selected for evaluation for both subjective color and marbling scores must have had at least 50% of lean muscle exposed in each package. The random selection for center-cut loin chops preference was given to boneless, 2.54-cm-thick center-cut loin chops. However, due to regional differences in pork availability, bone-in center-cut loin chops and/or the closest thickness for center-cut loin chop samples were also used for analysis as the situation depended necessary. When available, each 10 randomly selected packages of center-cut loin chops, sirloin chops, and blade steaks for each brand and enhancement type [enhanced (EN) and non-enhanced (NON)] were purchased. Purchased packages were placed in insulated coolers with frozen ice packs and shipped overnight to the designated location. All center-cut loin chops were shipped to Texas A&M University (TAMU). All sirloin chops and blade steaks were shipped to North Dakota State University (NDSU).

In-Laboratory Subjective Measurements

Once packages arrived at the designated location of either TAMU or NDSU, cooler arrival temperature was collected. Each package was then opened and allowed a minimum 10 minute "bloom time" prior to instrumental evaluation. The *Longissimus* muscle of center-cut loin chops, *Gluteus medius* muscle of sirloin chops, and the *Serratus ventralis* muscle of blade steaks were used for instrumental evaluation.

Minolta Color and pH Measurements

From each package 2 center-cut loin chops were randomly selected for Minolta color and pH measurements. Instrumental color (*CIE* L*, a *, and b* color space values) was measured using a Minolta Colorimeter (CR-300, 8 mm diameter head, 10° standard observer, D^{65} light source; Minolta Company, Ramsey, NJ) calibrated using a white tile. Center-cut loin chop pH was acquired using a portable pH meter (HI 98240; Hanna Instruments, Italy) fitted with a glass-tipped pH probe calibrated to pH 7.01 and 4.01 in 2 different buffer solutions. The probe was inserted into the middle of the *Longissimus* muscle of the center-cut loin chop.

When the dimension was large enough on the *Gluteus medius* muscle of the sirloin chop and the *Serratus ventralis* muscle of the blade steak to encompass the 50 mm diameter orifice of the Minolta Colorimeter (CR-410, 50 mm diameter orifice, 2° observer, C light source; Minolta

Company, Ramsey, NJ) color space values and pH (HI 99163, probe FC232D, Hanna Instruments, Italy), samples were evaluated.

Warner-Bratzler Shear Force

From each package 2 center-cut loin chops, not evaluated for instrumental color and pH, were selected for WBSF evaluation. The WBSF samples were vacuum-packaged and frozen until further evaluation. Prior to cooking, chops were thawed for 48 hours in a cooler at 4 °C. The center-cut loin chops were cooked using a clam-style cooker (George Foreman Grill; Spectrum Brands, Inc., Middleton, WI) to an internal temperature of 65 °C. Internal temperature was monitored using iron constantan thermocouples inserted into the geometric center of each chop (TT-J-36-SLE; Omega Engineering, Inc., Stanford, CT) and a hand-held temperature recorder (model HH-21; Omega Engineering, Inc., Stanford, CT). Center-cut loin chops were cooled for 4 hours to approximately 22.2 °C prior to shear force assessment. Four to six 1.27-cm diameter cores were removed from each chop parallel to the longitudinal orientation of the muscle fibers. Each core was sheared with a Warner-Bratzler shearing device (United Smart-1 Test System SSTM-500; United Calibration Corp., Huntington Beach, CA) perpendicular to the muscle fibers. A 1.168 cm Warner-Bratzler stainless steel blade was used to hold cores and a head speed of 200 mm/min was used with a 9.072 kg load cell to segment cores. Maximum force for each core was recorded in kg and analyzed as the average of the cores removed from each chop.

Techniques and processes for the assessment of WBSF in sirloin chops and blade steaks were similar; however, different equipment was used. Internal temperature of chops and steaks were monitored using a copper-constantan insulated wire (Neoflon PFA) and recorded using an Omega handheld digital thermometer (model HH801B; Omega Engineering, Inc., Stanford, CT).

Cores were sheared on a WBSF machine (G-R Electrical Manufacturing Co., Manhattan, KS) using the same settings across machines.

Statistical Analysis

Data was analyzed using mixed model procedures (PROC MIXED, SAS Institute, Cary, NC). Chop or steak served as the experimental unit. Models for each cut included region, enhancement type, and the interaction of region and enhancement type as fixed effects and a random effect of package nested within region, retailer, store, and brand. Least square means were calculated for enhancement type and region by enhancement type using the PDIFF option with the Tukey-Kramer adjustment for P-values. Correlations (PROC CORR, SAS Institute, Cary, NC) were assessed in defined groups of attributes due to the inability to collate color and pH measures directly with WBSF in center-cut loin samples because measures were not taken on the same chop within a package. Relationships between visual color and marbling in observed retail packages of center-cut loin chops; L*, a*, b*, and pH in purchased center-cut loin chops; and L*, a*, b*, pH, and WBSF in purchased sirloin chops and blade steaks were assessed.

2015 Materials and Methods

Retail Store Selection and Sampling

North Dakota State University, The Ohio State University, and The University of Florida collaborated to benchmark pork quality according to the 2013 Progressive Grocer Marketing Guidebook (Stagnito Media, 2013). The Progressive Grocer Marketing Guidebook did not include club stores, however for the purpose of this study, club stores were included in the study. Cities sampled were identified (Table 2.1.) from 7 different market regions. Retail stores within each city were selected based on the following criteria: 1) Geographic population distribution and major retailers, both national and regional. 2) Top 3 retail supermarkets in each city. 3) Retail stores where middle class income consumers most frequently purchase pork.

One hundred and thirty-three retail supermarkets, representing 29 cities from across 23 states were selected for the study (Table 2.2.). From each University there was a principal investigator assisted by a trained group of technical staff students. Three months prior to data collection, each principal investigator and the National Pork Board Retail Marketing Team met in Chicago, Illinois for a training session to plan, organize and discuss the data collection process, and to determine which specific stores and store locations within market regions would be visited for the study.

Boneless and bone-in center-cut loin chop, sirloin chop and blade steak samples were collected between January 2015 and April 2015 to eliminate any holiday or seasonal merchandizing variation. Retail supermarkets were visited between the hours of 09:00 A.M. and 17:00 P.M. In-store data collection parameters included:

1.) Store Information- date store was visited; store name and store identification number; address; state; zip; investigators; time store entered; time collection ended; linear footage in full and self-serve meat case for coffin, tiers and number of tiers; promotional items present for any pork, beef, poultry, other or none; stand up displays present for any pork, beef, poultry, other or none; cooking brochures for any pork, beef, poultry, other or none; coupons for any pork, beef, poultry, other or none; type of lighting (white LED, pink LED, or Florescent); three light (lumens) for tired and coffin display cases; compliance with pork nomenclature

2.) Self-Serve Pork Case Assessment: brand/packer; specific item description (nomenclature); cut (loin, sirloin, blade); bone-in or boneless; chop or roast; number of packages available; number of pieces per package; packaging type (modified atmosphere packaging, vacuum packaging, overwrap packaging); establishment number, product thickness (1,2, or 3); original price per pound; product label claims; recipe (sticker, price label, none); temperature recommendation (sticker, price label, none); temperature; sell-by-date; packed-on date, enhanced (yes or no); enhancement percent

3.) Package Quality Assessment: brand; packer; cut (loin, sirloin, blade); bone-in or boneless; package #; chop letter; color score (1-6); marbling (0-10); sell-by-date; blood splash; bruised; bone dust; purchased. Only center-cut loin chop (n= 3795) packages were randomly selected from the retail self-serve meat case and assessed under store lighting by an experienced grader for subjective color (NPB 1-6, 2011), and subjective marbling (NPB 1-10, 2011), and any pork quality defects including blood splash; bruised; bone dust.

In-Store Subjective Assessment

Subjective color score (NPB, 2011) under store lighting (1= pale, pinkish gray, to white to 6= dark, purplish red) was assessed on 10 randomly selected boneless and bone-in center-cut loin chop packages for each brand and enhancement type [enhanced (EN) or non-enhanced (NON)] by an experienced grader in the self-serve meat case. Subjective marbling score (NPB, 2011) under store lighting (1= practically devoid of marbling to 10= abundant of marbling) was assessed on 10 randomly selected boneless and bone-in center-cut loin chop packages for each brand and enhancement type [enhanced (EN) or non-enhanced (NON)] by an experienced grader in the self-serve meat case. Each center-cut loin chop was randomly selected for evaluation for both subjective color and marbling scores must have had at least 50% of lean muscle exposed in each package. The random selection for center-cut loin chops preference was given to boneless, 2.54-cm-thick center-cut loin chops. However, due to regional differences in pork availability, bone-in center-cut loin chops and/or the closest thickness for center-cut loin chop samples were also used for analysis as the situation depended necessary. When available, 10 packages containing a minimum of at least two center-cut loin chop, sirloin chop, and blade steak packages were purchased for each brand or enhancement type [enhanced (EN) or non-enhanced (NON)]. Sirloin chop and blade steak packages must have had at least 50% of lean muscle exposed in each package. Each of the 10 individual packages purchased were labeled one through 10. Depending on the number of center-cut loin chops available per package. Each center-cut loin chop that was analyzed received a letter (A to D) for record purposes. Once purchased, center-cut loin chop, sirloin chop, and blade steak packages were placed in either a Yeti Cooler or hard plastic cooler with reusable frozen ice packs. Coolers were shipped priority overnight to North Dakota State University (NDSU) for further subjective and instrumental measurements in the laboratory as described below.

In-Laboratory Subjective Measurements

Once coolers arrived at NDSU for in-laboratory assessment, arrival time and three internal cooler temperatures (top, middle, and bottom) were recorded. Additionally, all package information was re-recorded. Each package type was opened. Each center-cut loin chop, sirloin chop, and blade steak was placed on a foodservice tray and designated a center-cut loin chop, sirloin chop, or blade steak number. The center-cut loin chops, sirloin chops, and blade steaks were allowed a minimum 15 minute “bloom time”. After bloom, an experienced grader assessed each center-cut loin chop, sirloin chop, and blade steak for subjective color score according to the National Pork Board Color Standards (NPB, 2011) under controlled lighting. After determining color score, the experienced grader assessed the same center-cut loin chops, sirloin chops, and blade steaks for subjective marbling score according to the National Pork Board Marbling Standards (NPB, 2011) under controlled lighting in the laboratory.

Instrumental Color Measurement

After subjective analysis, instrumental color (*CIE* L*, a*, and b* color space values) was measured using a Minolta Colorimeter (CR-300, 8 mm diameter head, 10° standard observer, C light source; (Minolta Company, Ramsey, NJ), and calibrated to a white tile with Yxy data (Y = 94.8, x = 0.3131, y = 0.3191). The Minolta head was firmly placed in the center of the *Longissimus* muscle of the center-cut loin chop, *Gluteus medius* muscle of the sirloin chop and *Serratus ventralis* muscle of the blade steak on the surface of the meat to record the L*, a*, and b* color space values.

pH Measurement

A minimum of one randomly selected center-cut loin chop, sirloin chop, and blade steak from each package was used to obtain pH values. Center-cut loin chop, sirloin chop, and blade steak pH was acquired using a portable pH meter (HI 98240; Hanna Instruments, Italy) equipped with a glass tipped pH probe (FC232D; Hanna Instruments, Italy) and calibrated to pH 7.01 and 4.01 in two different buffer solutions. The probe was inserted directly into the middle of the *Longissimus* muscle of the center-cut loin chop, *Gluteus medius* muscle of the sirloin chop and *Serratus ventralis* muscle of the blade steak parallel to the cut surface. The pH probe was recalibrated after every 10 center-cut loin chops, sirloin chops, and blade steaks.

Warner-Bratzler Shear Force and Cook-Loss Percentage Measurements

Each center-cut loin chop, sirloin chop, and blade steak that was analyzed for subjective color, subjective marbling, and instrumental color was also selected for measuring tenderness using the Warner-Bratzler Shear Force (WBSF) method. Each center-cut loin chop, sirloin chop, and blade steak along with its chop identification number was individually placed in a vacuum package bag, was sealed and frozen at -20°C until thawed for WBSF measurement. Center-cut loin chops, sirloin chops, and blade steaks were thawed in the vacuum sealed package 24 hours in a cooler at 4°C. Once completely thawed, samples were removed from the vacuum sealed package and placed on a silver foodservice tray. Internal temperature was obtained using a large bore needle (14 g needle; Hamilton 7749-05 8" PTA N714). Each chop or steak had a copper-constantan insulated wire (Neoflon PFA) inserted into the geometric center of the *Longissimus* muscle of the center-cut loin chop, *Gluteus medius* muscle of the sirloin chop and *Serratus ventralis* muscle of the blade steak for each pork sample. Each cut was weighed prior to cooking ("on" weight) using a digital electronic weighing scale (model AND EK-300i; A&D Company Limited, Tokyo, Japan). The thermocouple was inserted into a hand-held Omega handheld digital thermometer (model HH801B; Omega Engineering, Inc., Stanford, CT) to determine "on" temperature. Before placing the cut onto the clam-style cooker (George Foreman Grill), the grill was preheated for approximately 10 minutes to 350°F (176.7°C) and the "on" time was recorded. All samples were placed on the grill with both cooking plates on both the top and bottom touching the lean surface. All samples were cooked until reaching an internal temperature of 65°C (149°F) then immediately removed from the grill. An "off" temperature and end time were recorded. Cooked samples were then placed back on a different foodservice tray. Five minutes after removal from the grill the samples were re-weighed to determine the cook-loss percentage. The samples were cooled for approximately 4 hours or to approximately 22.2°C prior to WBSF analysis. Six, 1.27-cm diameter cores parallel to the longitudinal orientation of the muscle fibers were removed from each cooked *Longissimus* muscle (center-cut loin chop), *Gluteus medius* muscle (sirloin chop), and the *Serratus ventralis* muscle (blade steak). All six cored samples were then sheared using the WBSF device (G-R Electrical Manufacturing Co., Manhattan, KA) perpendicular to the muscle fibers. Each of the six core samples were inserted and sheared between the 1.168 cm Warner-Bratzler stainless steel blade at a head speed of 200 mm/min used with a 9.072-kg load cell to segment cores. The maximum force for each of the six cores were recorded in kg and later were converted to Newton's from kg (1 kg= 9.80665002864 N).

Statistical Analysis

Simple statistics were calculated using means procedure in SAS (SAS Institute, Cary, NC). Data were analyzed using the mixed procedure in SAS with region, enhancement type, year, and their interactions as fixed effects. Package within region, retailer, and store number as random effect.

Results and Discussion

Product Demographics

Regional totals for the number of packages observed and purchased in 2012 are presented in Table 3.1 and regional totals for the number of packages observed and purchased in 2015 are presented in Table 2.2. In 2012, 531 EN and 660 NON packages of center-cut loin chops were observed in-store for subjective evaluation of color and marbling scores. Compared to 2015, in-store 427 EN and 1,028 NON packages of center-cut loin chops were observed for subjective assessment of color and marbling scores. Thus, there were more EN center-cut loin chop packages assessed for subjective color and marbling scores in-store in 2012 then 2015. As well, there were more NON center-cut loin chop packages assessed for subjective color and marbling scores in-store in 2015 then 2012. In 2012, instrumental evaluation included 577 EN and 683 NON center-cut loin chop, 207 EN and 124 NON sirloin chop, and 203 EN and 234 NON blade steak purchased packages. In 2015, instrumental evaluation included 427 EN and 1,080 NON center-cut loin chop packages, 78 EN and 155 NON sirloin chop packages, and 56 EN and 170 NON blade steak purchased packages. Therefore, for instrumental assessment, similar to in-store subjective color and marbling, there were more EN center-cut loin chop packages assessed than NON in 2012 then 2015, as well as there were more NON center-cut loin chop packages assessed for instrumental measurements in 2015 then 2012.

Table 3.1. 2012 Center-cut loin chop, sirloin chop, and blade steak demographics by region across the United States.

	Region[1]							National
	EC	MA	NE	PA	SE	SW	WC	
Center-Cut Loin Chops								
Cities included	8	10	3	15	13	5	13	67
Market areas included	5	4	2	6	6	3	6	32
Stores assessed	12	16	9	25	23	13	19	117
Brands assessed	10	13	10	17	12	9	17	57
Packages Observed[2]								
Enhanced	70	47	30	95	121	60	108	531
Non-enhanced	51	120	70	142	104	72	101	660
Packages Purchased[3]								
Enhanced	70	47	30	110	146	67	107	577
Non-enhanced	53	153	92	146	63	63	113	683
Sirloin Chops								
Cities included	3	3	3	12	11	5	8	45
Market areas included	3	3	2	6	7	3	6	30
Stores assessed	3	3	2	19	13	9	10	59
Brands assessed	3	3	2	12	7	4	8	31
Packages Purchased[4]								
Enhanced	11	6	1	82	44	31	32	207
Non-enhanced	10	14	5	58	12	9	16	124
Blade Steaks								
Cities included	6	5	2	11	10	3	9	16
Market areas included	5	2	2	6	6	3	6	30
Stores assessed	10	5	4	14	17	5	14	69
Brands assessed	6	5	3	10	9	5	13	35
Packages Purchased[4]								
Enhanced	38	10	6	41	75	5	28	203
Non-enhanced	50	15	9	53	36	11	60	234

[1] EC = East Central; MA = Mid-Atlantic; NE = New England; PA = Pacific; SE = Southeast; SW = Southwest; WC = West Central

[2] Number of packages of center-cut loin chops used for subjective, in-store assessment.

[3] Number of packages of center-cut loin chops purchased for instrumental assessment at Texas A&M University.

[4] Number of packages of sirloin chops and blade steaks purchased for instrumental assessment at North Dakota State University.

For instrumental assessment in sirloin chops, there were more EN packages assessed in 2012 then 2015. In 2015 there were more NON sirloin chop packages assessed for instrumental evaluation than in 2012. For blade steaks there were more EN packages assessed for instrumental measurements in 2012 then 2015. In 2015, there were more NON packages assessed for blade steak packages assessed for instrumental than in 2012. Overall, there were more EN packages available in 2012 then 2015, and there were more NON packages available in 2015 than 2012. One explanation for the difference in number of EN and NON packages available is the different brands available in the retail meat case for consumers. Currently, in general, consumers have a negative attitude towards enhancing pork due to the addition of non-meat ingredients, especially sodium and how it affects their health. McEwen and Mandell (2011) reported the trend for marketing non-enhanced pork is expected to increase due to potential health concerns associated with eating pork products enhanced with sodium and phosphate. From the present study we can certainly see a trend that there is less enhanced product available to consumers.

Regional differences in 2012, in product availability were found for sirloin chops, whereby the NE, EC, and MA regions offered a very limited selection of sirloin chops. In contrast, the PA region had a much greater selection of sirloin chops available. Blade steaks were more available within the EC, PA, SE, and WC regions than within the NE, MA, and SW regions. In 2015, regional differences in product availability were found for sirloin chops, by which the EC, MA, NE and SW regions offered a very constrained selection of sirloin chops. In contrast for sirloin chop packages, the PA and WC regions had a much larger selection for purchase. Similarly, for blade steaks, the EC, MA, NE, SE, and SW regions offered very constrained selection of blade steaks. There were no blade steaks available in the MA region. Whereas, blade steaks were more readily available for purchase within the PA, SE, and WC regions. Similarly, in comparing 2012 and 2015, sirloin chops in the EC, NE and SW regions all offered a lesser amount of sirloin chops, as well as for both years the PA region offered a greater amount of sirloin chops. There was less selection available for blade steaks in the SE and SW region in 2015 then 2012, but for both years the EC, MA and SE regions offered a lesser amount available of blade steaks. Both years in the PA region sirloin chops were more readily available for selection, yet in 2015 the WC region also had a larger selection for sirloin chops, in which 2012 the WC did not offer more product.

Subjective Pork Quality Attributes

National mean simple statistics for subjective color and marbling are presented in Table 3.2 for 2012 and Table 2.3 for 2015. The 2012 mean subjective center-cut loin chop color score value observed in the store (n= 2788) was 3.12 (± 0.85). The 2015 mean subjective center-cut loin chop color score value observed in the sore (n= 3795) was 2.85 (± 0.79). Due to current events of the West Port Union dispute in 2015, when center-cut loin chops were purchased between January and April 2015, the 2015 subjective color results were expected to obtain a higher color score from the additional percentage of meat stored in cold storage and not exported to other countries that pay premiums to processors for darker colored meat. Yet, based on the results, this was not the case. Both mean subjective color score values of 3.12 (± 0.85) and 2.85 (± 0.79) were lower than 3.52 (± 0.85) observed by Wright et al. (2005) in loin chops in the retail meat case. Since the last analyzation of benchmarking pork quality in the retail meat case, the subjective color score has decreased.

The 2012, mean subjective center-cut loin chop marbling score value observed in the store (n= 2760) was 2.48 (± 0.95). The 2015 mean subjective center-cut loin chop marbling score value observed in the sore (n= 3795) was 2.30 (± 1.02). Mean subjective marbling score was

2.48 (± 0.95) in 2012 (n= 2760) and 2.30 (± 1.07) in 2015 (n= 3795). Mean subjective marbling score in the 2012 benchmarking study was slightly greater than 2.37 (± 0.86) observed in boneless loin chops by Wright et al. (2005) and 2.43 (± 1.27) observed in pork loins by Moeller et al. (2010a). In contrast, from the current benchmarking study the mean subjective marbling score was slightly lower than 2.37 (± 0.86) observed by Wright et al. (2005) and 2.43 (± 1.27) observed by Moeller et al. (2010a). Subjective color and marbling results from 2012 and 2015 are not consistent with one another or with previous literature quantifying mean color and marbling scores in center-cut loin chops.

Table 3.2. 2012 National representation of simple statistics of center-cut loin chop, sirloin chop, and blade steak quality attributes.

	n	Mean	Minimum	Maximum	SD	CV%
Center-cut loin chops						
Color[1]	2788	3.12	1.00	6.00	0.85	27.2
Marbling[2]	2760	2.48	1.00	6.00	0.95	38.3
L*[3]	1707	55.30	41.44	68.62	3.70	6.7
a*[4]	1708	5.89	-6.90	16.96	3.12	53.0
b*[5]	1708	3.73	-2.87	11.78	1.86	49.9
pH	1799	5.86	4.60	6.85	0.27	4.6
WBSF[6], N	1912	23.39	8.38	63.59	6.82	29.2
Sirloin chops						
L*[3]	918	51.92	43.06	61.64	3.22	6.2
a*[4]	918	19.50	9.44	27.07	2.74	14.1
b*[5]	918	10.06	5.38	71.78	2.63	26.1
pH	1063	5.88	5.11	6.87	0.29	4.9
WBSF[6], N	1019	18.71	7.71	40.11	5.17	27.6
Blade steaks						
L*[3]	829	45.27	38.76	56.66	2.79	6.2
a*[4]	829	19.70	11.54	26.67	2.12	10.8
b*[5]	829	8.13	3.79	12.44	1.71	21.0
pH	850	6.22	5.55	6.98	0.27	4.3
WBSF[6], N	749	17.12	7.08	39.86	4.65	27.2

[1] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011).
[2] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011).
[3] Lightness scale: 0 = black; 100 = white.
[4] Redness scale: < 0 = green; > 0 = red.
[5] Yellowness scale: < 0 = blue; > 0 = yellow.
[6] WBSF = Warner-Bratzler shear force.

Least square means of enhanced and non-enhanced center-cut loin chops, sirloin chops, and blade steaks for 2012 are presented in Table 3.3 and for 2015 are presented in Table 2.4.

Table 3.3. 2012 Least square means (S.E.) of enhanced (EN) and non-enhanced (NON) center-cut loin chop, sirloin chop, and blade steak quality attributes nationwide.

	EN	NON	P-value
Center-cut loin chops			
Color[1]	3.25 (0.04)	3.17 (0.03)	0.08
Marbling[2]	2.32 (0.04)	2.50 (0.03)	<0.001
L*[3]	54.06 (0.16)	56.06 (0.14)	<0.001
a*[4]	5.81 (0.14)	6.18 (0.13)	0.05
b*[5]	3.61 (0.08)	3.75 (0.07)	0.17
pH	5.96 (0.01)	5.77 (0.01)	<0.001
WBSF[6], N	20.83 (0.28)	25.20 (0.24)	<0.001
Sirloin chops			
L*[3]	51.35 (0.52)	52.27 (0.30)	0.12
a*[4]	20.04 (0.42)	17.75 (0.27)	<0.001
b*[5]	9.63 (0.40)	10.26 (0.20)	0.16
pH	6.00 (0.04)	5.68 (0.02)	<0.001
WBSF[6], N	15.99 (0.58)	23.00 (0.39)	<0.001
Blade steaks			
L*[3]	45.06 (0.28)	45.08 (0.24)	0.97
a*[4]	20.70 (0.19)	18.89 (0.17)	<0.001
b*[5]	8.36 (0.16)	7.85 (0.14)	0.02
pH	6.22 (0.03)	6.18 (0.02)	0.31
WBSF[6], N	15.76 (0.44)	17.13 (0.39)	0.02

[1] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011).
[2] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011).
[3] Lightness scale: 0 = black; 100 = white.
[4] Redness scale: < 0 = green; > 0 = red.
[5] Yellowness scale: < 0 = blue; > 0 = yellow.
[6] WBSF = Warner-Bratzler shear force.

In 2012, EN center-cut loin chops had numerically greater subjective color score than NON (3.25 vs. 3.17, respectively, $P = 0.08$). In 2015, EN center-cut loin chops had a higher (darker color) mean subjective color score than NON (3.07 vs. 2.74, respectively, $P < 0.0001$). Results show for both years, EN center-cut loin chops were darker both under store lighting, and under controlled lighting in-laboratory than NON center-cut loin chops. In 2012, EN center-cut loin chops had numerically lower subjective marbling than NON (2.39 vs. 2.47, respectively, P =

0.08). In 2015, there were similar results, EN center-cut loin chops significantly had lower subjective marbling score than NON (2.02 vs. 2.32, respectively, $P < 0.0001$). In 2012, sirloin chops and blade steaks were not assessed for subjective color and marbling scores in-laboratory, however in 2015 sirloin chops and blade steaks were assessed for subjective color and marbling scores in-laboratory. Therefore, from the present study, EN sirloin chops had a higher subjective color score than NON (3.04 vs. 3.12, respectively). EN and NON sirloin chops had the same subjective marbling score of 1.97. EN blade steaks had a similar subjective color score than NON (4.73 vs 4.72, respectively). EN blade steaks significantly had a higher subjective marbling score than NON (3.06 vs 2.87, respectively). Overall, regardless of enhancement type, blade steaks had greater subjective color and marbling scores than both center-cut loin chops and sirloin chops.

The interaction of enhancement type by region were observed for subjective color and marbling scores for center-cut loin chops, sirloin chops, and blade steaks (Table 3.4) in 2012 and (Table 2.5) in 2015. In 2012, the SW region significantly had a greater subjective color score in EN center-cut loin chops than NON (3.89 vs. 3.30; $P < 0.01$) with no differences ($P > 0.90$) observed in other regions. Subjective marbling score was lower for EN center-cut loin chops than NON in the EC (2.34 vs. 2.95; $P < 0.01$), MA (1.99 vs. 2.28; $P < 0.01$, and SE (2.60 vs. 3.05; $P < 0.01$) regions but did not differ ($P > 0.70$) in the other regions. In 2015, the SW region significantly had a greater in-store subjective color score (darker color) for EN center-cut loin chops than NON (3.61 vs. 2.78; $P < 0.05$), with no differences observed ($P > 0.36$) in the other regions. Subjective marbling score evaluated in-store was significantly lower for EN center-cut loin chops than NON in the SE (1.66 vs 2.44; $P < 0.05$) and WC (1.86 vs 2.38; $P < 0.05$) regions but did not differ ($P > 0.33$) in the other regions. In both 2012 and 2015 the SW region significantly had a greater subjective color score in EN center-cut loin chops than NON. Additionally, results from both studies in the SE region, EN center-cut loin chops had significantly lower subjective marbling scores. However, in 2012 in the EC and MA regions for EN center-cut loin chops had significantly lower subjective marbling scores. While in 2015 there were no significant differences between enhancement type in the EC and MA region, but did have significant lower EN subjective marbling score in the WC region than NON, but no observed differences in the WC region in 2012. The enhancement type by region interactions for subjective color and marbling in 2012 and 2015 are not simply explained, but are not likely due to observer bias as experienced graders obtained information in multiple regions.

Table 3.4. 2012 Least squares means (S.E.) per region of enhanced (EN) and non-enhanced (NON) center-cut loin chop quality attributes.

	Region[1]														*P*-values		
	EC		MA		NE		PA		SE		SW		WC				
	EN	NON	EN	NON	EN	NON	EN	NON	EN	NON	EN	NON	EN	NON	R	E	R*E
Center-cut loin chops																	
Color[2]	2.66 (0.09)	2.84 (0.10)	3.28 (0.11)	3.08 (0.06)	3.60 (0.14)	3.65 (0.08)	3.37 (0.07)	3.29 (0.06)	3.30 (0.06)	3.35 (0.07)	3.89[a] (0.09)	3.30[b] (0.10)	2.69 (0.07)	2.70 (0.07)	<0.01	0.08	<0.01
Marbling[3]	2.34[a] (0.10)	2.95[b] (0.11)	1.99 (0.13)	2.28 (0.07)	2.07 (0.16)	2.19 (0.09)	2.34 (0.08)	2.34 (0.07)	2.60[a] (0.07)	3.05[b] (0.08)	2.44 (0.11)	2.33 (0.11)	2.42 (0.08)	2.34 (0.08)	<0.01	<0.01	<0.01
L*[4]	54.90 (0.39)	56.74 (0.46)	53.90[a] (0.49)	57.29[b] (0.28)	54.22 (0.66)	55.41 (0.38)	54.76 (0.33)	55.81 (0.29)	55.12 (0.27)	56.62 (0.46)	51.02[a] (0.42)	55.28[b] (0.42)	54.50 (0.33)	55.29 (0.32)	<0.01	<0.01	<0.01
a*[5]	4.68 (0.35)	6.11 (0.40)	5.56[c] (0.44)	7.13[d] (0.25)	6.81 (0.57)	6.24 (0.33)	5.39 (0.29)	6.35 (0.25)	5.82 (0.24)	4.82 (0.40)	8.15 (0.36)	7.97 (0.37)	4.25 (0.29)	4.63 (0.28)	<0.01	0.05	<0.01
b*[6]	3.10 (0.19)	4.03 (0.23)	4.31[a] (0.24)	2.94[b] (0.14)	3.47 (0.32)	3.51 (0.19)	3.19[a] (0.16)	4.24[b] (0.14)	3.50 (0.14)	3.28 (0.23)	2.89 (0.21)	3.10 (0.21)	4.78 (0.16)	5.17 (0.16)	<0.01	0.17	<0.01
pH	5.90[a] (0.03)	5.75[b] (0.03)	5.89[a] (0.04)	5.74[b] (0.02)	5.80 (0.05)	5.70 (0.03)	5.93[c] (0.02)	5.83[d] (0.02)	5.94[a] (0.02)	5.81[b] (0.03)	6.25[a] (0.03)	5.75[b] (0.03)	5.97[a] (0.02)	5.82[b] (0.02)	<0.01	<0.01	<0.01
WBSF[7], N	23.18 (0.67)	24.88 (0.79)	19.40[a] (0.94)	24.22[b] (0.52)	22.14 (1.10)	24.41 (0.62)	20.03[a] (0.57)	26.33[b] (0.50)	21.77[a] (0.48)	24.59[b] (0.72)	17.27[a] (0.72)	25.51[b] (0.71)	21.99[a] (0.57)	26.43[b] (0.54)	<0.01	<0.01	<0.01
Sirloin chops																	
L*[4]	50.15[a] (0.87)	55.44[b] (0.87)	51.36 (1.42)	49.91 (0.75)	51.54 (3.14)	51.28 (1.09)	52.42 (0.27)	52.12 (0.36)	51.29 (0.37)	51.87 (0.88)	50.42 (0.45)	52.71 (0.75)	52.25 (0.44)	52.57 (0.67)	0.20	0.12	<0.01
a*[5]	22.21[a] (0.77)	16.74[b] (0.77)	20.05 (1.26)	18.03 (0.65)	17.43 (2.48)	18.17 (0.97)	20.01[a] (0.24)	18.14[b] (0.31)	20.15[a] (0.33)	15.52[b] (0.78)	20.01 (0.39)	20.42 (0.70)	20.43[a] (0.38)	17.19[b] (0.58)	<0.01	<0.01	<0.01
b*[6]	9.08 (0.58)	10.83 (0.58)	10.21 (0.95)	8.61 (0.53)	9.02 (2.51)	10.27 (0.72)	10.49 (0.18)	10.19 (0.25)	9.94 (0.25)	11.72 (0.60)	8.74[a] (0.30)	11.65[b] (0.45)	9.94 (0.30)	8.54 (0.47)	<0.01	0.16	<0.01
pH	6.21[a] (0.07)	5.63[b] (0.07)	5.94 (0.12)	5.87 (0.06)	5.89 (0.21)	5.36 (0.09)	5.83 (0.02)	5.73 (0.03)	6.01[a] (0.03)	5.71[b] (0.07)	6.22[a] (0.04)	5.73[b] (0.06)	5.88[a] (0.04)	5.71[b] (0.05)	<0.01	<0.01	<0.01
WBSF[7], N	15.30[a] (1.08)	25.44[b] (1.10)	14.56 (1.73)	18.99 (0.91)	15.60 (3.39)	24.75 (1.52)	16.91[a] (0.35)	23.61[b] (0.44)	17.88 (0.46)	19.85 (1.11)	14.74[a] (0.56)	20.03[b] (1.02)	16.93[a] (0.54)	25.31[b] (0.81)	<0.01	<0.01	<0.01
Blade steaks																	
L*[4]	44.69 (0.34)	45.85 (0.53)	45.34 (0.68)	45.62 (0.65)	45.37 (1.20)	43.49 (0.94)	45.37 (0.40)	44.71 (0.38)	46.61 (0.30)	45.36 (0.61)	43.51 (1.11)	45.01 (0.84)	44.55 (0.48)	45.49 (0.33)	0.16	0.97	0.04
a*[5]	18.90 (0.23)	18.73 (0.36)	21.60[a] (0.46)	19.36[b] (0.44)	22.28[c] (0.82)	18.93[d] (0.64)	20.95[a] (0.27)	19.18[b] (0.26)	20.26[a] (0.20)	18.15[b] (0.42)	20.19 (0.76)	19.19 (0.57)	20.72[a] (0.33)	18.70[b] (0.23)	<0.01	<0.01	<0.01
b*[6]	7.72 (0.19)	8.52 (0.31)	9.39[c] (0.39)	7.72[d] (0.37)	9.56 (0.69)	8.28 (0.54)	8.94 (0.23)	8.05 (0.22)	8.94[a] (0.17)	7.56[b] (0.35)	6.58 (0.64)	6.82 (0.48)	7.41 (0.28)	8.00 (0.19)	<0.01	0.02	<0.01
pH	6.17 (0.03)	6.09 (0.05)	6.28 (0.07)	6.26 (0.06)	6.06 (0.11)	6.04 (0.09)	6.23 (0.04)	6.22 (0.04)	6.29 (0.03)	6.17 (0.06)	6.35 (0.11)	6.37 (0.09)	6.13 (0.05)	6.11 (0.03)	<0.01	0.31	0.84
WBSF[7], N	17.77 (0.55)	16.48 (0.85)	15.02[a] (1.06)	19.82[b] (0.96)	15.75 (1.90)	13.84 (1.51)	15.92 (0.64)	17.84 (0.61)	16.77 (0.47)	18.06 (0.95)	13.38 (1.70)	14.06 (1.43)	15.69[a] (0.87)	19.83[b] (0.54)	0.02	0.02	<0.01

Table 3.4. 2012 Least squares means (S.E.) per region of enhanced (EN) and non-enhanced (NON) center-cut loin chop quality attributes (continued).

[1] EC = East Central, MA = Middle Atlantic, NE = New England, PA = Pacific, SE = Southeast, SW = Southwest, WC = West Central.
[2] Color scale: 1 = pale pinkish gray to white; 6 = dark purplish red (NPB, 2011).
[3] Marbling scale: 1 = devoid; 10 = abundant (NPB, 2011).
[4] Lightness scale: 0 = black; 100 = white.
[5] Redness scale: < 0 = green; > 0 = red.
[6] Yellowness scale: < 0 = blue; > 0 = yellow.
[7] WBSF = Warner-Bratzler shear force.
[a, b] Least square means with a, b in the same region differ by $P < 0.05$.
[c, d] Least square means with c, d in the same region differ by $0.05 < P < 0.10$.

Instrumental Pork Quality Attributes

The simple statistics for center-cut loin chop, sirloin chop, and blade steak quality attributes of purchased pork are presented in Table 3.2 for 2012 and Table 2.3 for 2015. Between 2012 and 2015, the mean Minolta L* values were (55.30 vs. 55.56, respectively) for center-cut loin chops, (51.92 vs. 52.46, respectively) for sirloin chops, and (45.27 vs/ 45.84, respectively) for blade steaks. The 2012 versus 2015 mean Minolta a* values were (5.89 vs. 16.60, respectively) for center-cut loin chops, (19.50 vs. 17.34, respectively) for sirloin chops, and (19.70 vs. 18.97, respectively) for blade steaks. The 2012 versus 2015 mean Minolta b* values were (3.73 vs. 10.33, respectively) for center-cut loin chops. (10.06 vs. 9.79, respectively) for sirloin chops, and (8.13 vs. 7.92, respectively) for blade steaks. The mean pH values were (5.86 vs. 5.83, respectively) for center-cut loin chops, (5.88 vs. 5.90, respectively) for sirloin chops, and (6.22 vs. 6.28, respectively) in blade steaks. The mean WBSF values were (23.39 N vs. 24.25 N, respectively) for center-cut loin chops, (18.71 N vs. 20.80 N, respectively) for sirloin chops, and (17.12 N vs. 17.41 N, respectively) for blade steaks. From both studies, the results indicate blade steaks were darker in color (< L*) and had the most red (> a*) compared to other cuts. Contrary, center-cut loin chops were whiter (> L*) and had the least red (< a*). Additionally, blade steaks had the greatest pH value, whereas center-cut loin chops and sirloin chops had similar pH values. Warner-Bratzler Shear Force mean values for blade steaks and sirloin chops were less (more tender) then center-cut loin chops (more tough). Profiling pork muscle reports (Porcine Myology) exhibit that the *Longissimus* muscle of center-cut loin chops has a lesser proportion of Type I (red muscle fibers) compared to Type IIB (white muscle fibers), where the *Serratus ventralis* muscle of the blade steak has a larger proportion of Type I muscle fiber types. These would suggest the *Serratus ventralis* muscle exhibits a lower L* value, a greater a* and greater pH when compared to the other two cuts.

In 2012, EN center-cut loin chops were significantly darker (lower Minolta L* value) than NON (54.31 vs 56.10, respectively, $P < 0.01$). The results could be due to the fact that enhancing pork with non-meat ingredients results in a greater pH so less proteins are denatured during the conversion of muscle to meat, causing less water-loss and ultimately less moisture on the cut surface that does not reflect as much light, but instead absorbs more light. EN sirloin chops had a slightly lower Minolta L* value than NON (51.35 vs. 52.27, respectively, $P = 0.12$) indicating EN sirloin chops were darker in color than NON chops. EN blade steaks Minolta L* were closely similar between EN and NON (45.05 vs. 45.08; $P = 0.95$). Therefore, the results explain EN blade steaks were darker in color compared to NON. EN sirloin chops Minolta a* values were significantly greater than NON (20.06 vs. 17.68, respectively, $P < 0.01$), concluding EN blade steaks were more red then NON. Similar to sirloin chops, EN blade steaks Minolta a* values were significantly greater than NON (20.79 vs. 18.89, respectively, $P < 0.01$). EN center-cut loin chops significantly had a lower Minolta b* value than NON (3.62 vs. 3.82; $P = 0.05$). In contrast, EN blade steaks significantly had a higher Minolta b* value than NON (8.37 vs. 7.85; $P = 0.02$).

In 2015, EN center-cut loin chops were significantly ($P < 0.0001$) darker (lower Minolta L* value) than NON (54.46 vs 56.00, respectively). The results could be due to the fact that enhancing pork with non-meat ingredients results in a greater pH so less proteins are denatured, causing less water-loss and ultimately less water on the cut surface that does not reflect as much light. EN sirloin chops had a slightly higher Minolta L* value than NON (53.74 vs. 52.51, respectively, $P = 0.20$), indicating EN sirloin chops were lighter in color than NON. EN blade steaks Minolta L* were closely similar between EN and NON (45.81 vs. 45.96, respectfully). Therefore, the results explain EN blade steals were darker in color compared to NON. EN sirloin chops Minolta a* were significantly greater than NON (17.30 vs. 16.24, respectively, $P = 0.09$). Similar to sirloin chops, EN blade steaks had a Minolta a* value significantly greater or more positive red than NON (19.04 vs. 17.84, respectively, $P = 0.01$). Overall, in 2012 and 2015 EN center-cut loin chops significantly had a lower Minolta L* than NON, and both studies found no significant differences in EN and NON Minolta L* values for sirloin chops or blade steaks. Yet, in 2012, for all cuts, EN (54.31 vs. 54.46, respectively) center-cut loin chops, (51.33 vs. 53.74, respectively) sirloin chops, and (45.05 vs. 45.81, respectively) blade steaks, had a lower Minolta L* than in 2015. Thus, EN center-cut loin chops, sirloin chops, and blade steaks were darker in color in 2012 then 2015. In contrast, NON center-cut loin chops had a lower Minolta L* value in 2015 than 2012 (56.10 vs. 56.00, respectively). In 2012 versus 2015, NON sirloin chops (52.24 vs. 52.51, respectively) and blade steaks (45.08 vs. 45.96, respectively) had a lower Minolta L* value. Thus, NON sirloin chops and blade steaks were darker in color in 2012 then 2015, but not for center-cut loin chops. EN center-cut loin chop a* was greater in 2015 then 2012 (5.61 vs. 16.19, respectively). EN sirloin chops (20.06 vs. 17.30, respectively) and blade steaks (20.79 vs. 19.04, respectively) a* value was greater (more red) in 2012 then 2015. NON center-cut loin chops (3.82 vs. 10.38, respectively) and sirloin chops (9.69 vs. 10.21, respectively) b* was greater in 2015 then 2012. Similar to EN blade steaks, NON blade steaks b* was greater in 2012 then 2015 (8.37 vs. 8.18, respectively).

In 2012, mean pH values for center-cut loin chops, sirloin chops, and blade steaks are presented in Table 3.2. The mean pH values were 5.86 (± 0.27) for center-cut loin chops, 5.88 (± 0.29) for sirloin chops, 6.22 (± 0.27) for blade steaks. EN center-cut loin chops significantly had a higher pH value than NON (5.98 vs 5.78, $P < 0.01$). EN sirloin chops significantly had a higher pH value than NON (6.01 vs. 5.68, $P < 0.01$). EN blade steaks had no significant difference pH than NON (6.22 vs. 6.16, $P = 0.15$). In 2015, results for the mean pH values for center-cut loin chops, sirloin chops, and blade steaks are presented in Table 2.3. The mean pH values were 5.83 (± 0.32) for center-cut loin chops, 5.90 (± 0.30) for sirloin chops, and 6.28 (± 0.33) for blade steaks. EN center-cut loin chops significantly had a higher pH value than NON (6.00 vs 5.74, $P < 0.0001$) (Table 2.4). EN sirloin chops significantly had a higher pH value than NON (6.00 vs. 5.89, $P = 0.04$). EN blade steaks significantly had a higher pH than NON (6.42 vs. 6.28, $P = 0.04$). Overall, as anticipated, enhancing pork significantly increases the pH value for all product categories. EN center-cut loin chops (6.00 vs. 5.98, respectively) and blade steaks (6.22 vs. 6.42, respectively) had a higher pH in 2012 then 2015. EN sirloin chops had a slightly higher pH value in 2012 then 2015 (6.01 vs. 6.00, respectively). NON center-cut loin chops had a higher pH value in 2012 then 2015 (5.78 vs. 5.74, respectively). NON sirloin chops (5.68 vs. 5.89, respectively) and blade steaks (6.16 vs. 6.28, respectively) had a lower pH values in 2012 then 2015. Miller (2002) reported the addition of water, sodium or phosphates increases the pH that allows proteins to bind more free water, and less moisture on the cut surface, resulting in less light reflection and in turn appears darker. Thus, retailers have the option to present darker pork to consumers by enhancing pork.

For tenderness, using the Warner-Bratzler Shear Force (WBSF) method. In 2012, the mean values were 23.39 N (± 6.82) for center-cut loin chops, 18.71 N (± 5.17) for sirloin chops, and 17.12 (± 4.65) for blade steaks. EN center-cut loin chops were significantly more tender (lower WBSF value) than NON (21.00 vs. 25.24 N, $P < 0.01$). EN sirloin chops were significantly more tender (lower WBSF value) than NON (15.99 vs. 23.00 N, $P < 0.01$). EN blade steaks were significantly more tender (lower WBSF value) than NON (15.76 vs. 17.13 N, P = 0.02). All cuts had a mean WBSF value lower than what Moeller et al. (2010b) reported with a trained sensory panelist that favored pork with a WBSF value less than 24.5 N but could determine the difference in tenderness for every 4.9 N increase above 24.5 N and did not favor this pork. Thus, in 2012, all cuts, regardless of enhancement type can be classified as tender pork. In 2015, the mean WBSF values were 24.25 N (± 7.23) for center-cut loin chops, 20.80 N (± 6.71) for sirloin chops, and 17.41 N (± 4.78) for blade steaks (Table 2.4). EN center-cut loin chops were significantly more tender (lower WBSF value) than NON (20.43 vs. 25.99 N, P < 0.0001). EN sirloin chops were significantly more tender (lower WBSF value) than NON (16.18 vs. 22.92 N, P < 0.0001). EN blade steaks were significantly more tender (lower WBSF value) than NON (15.74 vs. 19.42 N, P = 0.0005). EN center-cut loin chops (21.00 vs. 20.43 N, respectively) and blade steaks (15.76 vs. 15.74 N, respectively) were more tough (higher WBSF value) in 2012 then 2015. EN sirloin chops were more tender (lower WBSF value) in 2012 then 2015 (15.99 vs. 16.18 N, respectively). NON center-cut loin chops (25.24 vs. 25.99 N, respectively) and blade steaks (17.13 vs. 19.42 N, respectively) were more tender in 2012 then 2015.All product categories had a mean WBSF value lower than what Moeller et al. (2010b) reported from a trained panelist that favored pork with a WBSF value less than 24.5 N but could determine the difference in tenderness for every 4.9 N increase above 24.5 N and did not favor this pork. Therefore, all cuts and enhancement type, from both studies can be classified nationwide as tender.

The differences in region, enhancement type and the interaction of region by enhancement type are presented in Table 3.4 for 2012. Where regional differences in L* were significant (i.e. SW), greater L* values and lesser pH values for NON chops corresponded to increased WBSF values when compared to EN chops. Findings for sirloin chops were different for L* across the regions, with enhancement improving L* (darker) numerically in the EC, SE, SW, and WC regions; however, enhancement improved pH (greater) and WBSF (lesser) numerically in all regions and significantly in EC, SE, SW, and WC regions. Conversely, enhancement had little practical effect on L*, no effect on pH across the regions, and inconsistently small effects on WBSF of the blade steaks, a cut that inherently was darker as measured by L*, of a greater pH, and the most tender as indicated by WBSF. In 2015, the effect of enhancement type [enhanced (EN) and non-enhanced (NON)] (Table 2.4.) and enhancement type [enhanced (EN) and non-enhanced (NON)] within region (Table 2.5.) on pork quality were dependent on product cut and region. The Minolta L* value for EN center-cut loin chops was significantly lower (darker color) in the SW (52.2 vs. 52.4, $P < 0.05$), and SW (52.4 vs. 55.2, $P < 0.05$) regions but no differences were observed ($P > 0.98$) in the other regions. There were no differences for Minolta L* value for EN and NON sirloin chops in any of the regions. The Minolta L* value for NON blade steaks was significantly lower (darker color) in the PA (47.5 vs. 44.76, $P < 0.05$) region than NON blade steaks. Also, NON blade steaks had a tendency to have a lower Minolta L* in the WC (47.1 vs. 44.7, $0.05 < P < 0.10$) region than EN, but no differences were observed ($P > 0.99$) in the other regions. The Minolta a* value for EN center-cut loin chops was significantly higher (more red) in the WC (19.0 vs. 17.0, $P < 0.05$) region than NON, but no differences were observed ($P > 0.41$) in the other regions. Likewise, the Minolta a* value for EN blade steaks were significantly higher (more red) in the WC (21.8 vs. 19.2, $P < 0.05$) region than NON, but no differences were observed ($P > 0.11$) in the other regions. For Minolta b*, NON center-cut loin chops significantly had a higher b* value in the PA (9.7 vs. 10.4, $P < 0.05$), SE (8.8 vs. 10.9, $P < 0.05$), and SW (8.8 vs. 10.2, $P < 0.05$) regions than EN, but no differences were observed ($P > 0.43$) in the other regions. While, EN blade steaks significantly had a higher Minolta b* value (more yellow) in the PA (9.4 vs. 6.9, $P < 0.05$) region, and EN blade steaks had a tendency difference to have a higher Minolta b* in the WC (9.0 vs. 7.7, $0.05 < P < 0.10$) region than NON, but no differences were observed ($P > 0.96$) in the other regions. Many of the regions had significant differences in pH for enhancement type. EN center-cut loin chops significantly had a higher pH value in the PA (6.0 vs. 5.8, $P < 0.05$), SE (6.3 vs. 5.7, $P < 0.05$), SW (6.4 vs. 5.8, $P < 0.05$), and WC (6.0 vs. 5.8, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.99$) in the other regions. While, EN blade steaks significantly had a higher pH value in the PA (6.5 vs. 6.2, $P < 0.05$), and SE (6.9 vs. 6.3, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.14$) in the other regions. A majority of the regions had significant differences in tenderness (WBSF) for enhancement type. EN center-cut loin chops significantly had a lower WBSF (more tender) value in the PA (18.8 vs. 25.8 N, $P < 0.05$), SE (17.8 vs. 25.6 N, $P < 0.05$), SW (18.2 vs. 25.7, $P < 0.05$), and WC (18.9 vs. 25.7, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.14$) in the other regions. EN sirloin chops significantly had a lower WBSF (more tender) value in the PA (18.4 vs. 23.3 N, $P < 0.05$), and WC (14.6 vs. 21.3 N, $P < 0.05$) regions than NON, but no differences were observed ($P > 0.44$) in the other regions. EN blade steaks only had a tendency difference to have a lower WBSF in the PA (15.7 vs. 19.2 N, $0.05 < P < 0.10$) region compared to NON, but no differences were observed ($P > 0.14$) in the other regions. Overall, there were varying differences between the interaction of enhancement type and region from this present study. One major difference between the 2012 and 2015 study is for Minolta L*, a*, b*, pH, and WBSF least square means per region. In 2012, the least square means included region, enhancement type and the interaction between region and enhancement type, whereas in 2015 it only included enhancement type and the interaction between region and enhancement type. However, both in 2012 and 2015 there were significant differences in Minolta L* enhancement types in the SE and SW regions for center-cut loin chops. In 2012, there were additional differences in Minolta L* for the EC, MA, and PA regions. In 2015 there were no differences for sirloin chop Minolta L* values, but in 2012 there were differences in enhancement type in the EC and SW region. For blade steaks Minolta L* in 2012, there were no differences by enhancement type or region, but in 2015 there was a difference in the PA region and a tendency difference in the WC region. For Minolta a* in center-cut loin chops, comparing 2012 to 2015, there were no similar regions with significant differences in enhancement type. In 2012, there were Minolta a* value differences between EN and NON in the EC, MA, PA, SE and SW regions for center-cut loin chops, whereas in 2015 there was only a significant difference in the WC region for center-cut loin chops. Similarly, in sirloin chops there were no similar regions where there were significant differences in enhancement type for Minolta a*. In 2012, there was significant difference in enhancement type in the EC, PA, SE, and WC regions for Minolta a*, but there were no differences found in 2015. Blade steaks Minolta a* value, WC was the only region that both the 2012 and 2015 found significant differences in enhancement type by region. In 2012, there were additional significant differences in the MA, NE, PA, SE, and SW regions. Center-cut loin chop Minolta b* differences were only similar in the PA region for both years. In 2012, there were additional differences in enhancement type by region in the EC, and MA regions, but in 2012, additional differences were also found in SE, and SW regions. There were no differences in 2015 for Minolta b*, but in 2012 there were regional differences in enhancement type for the EC, PA, SW, and WC regions. Blade steaks b* differences were only similar in the PA region for both years. In 2012, there were additional differences in enhancement type for blade steak Minolta b* for the EC, MA, and SE regions. As well, in 2015 there was a tendency difference in enhancement type in the WC region for blade steak Minolta b* value. In both studies, there were significant differences in enhancement type in the PA, SE, SW, and WC regions for pH. However, in 2012, there was also a significant difference in enhancement type in the EC, and MA regions for pH. For sirloin chops, there were no similar significant differences per region for pH in 2012 and 2015. In 2012, there were significant pH differences in enhancement type in the EC, NE, PA, SE, SW, and WC regions, but there were no enhancement type differences in sirloin chops in pH per region in 2015. For blade steaks, there were no similar significant differences per region for pH in 2012 and 2015. In 2015, there were significant pH differences in enhancement type in the PA, and SE regions, but there were no enhancement type differences in sirloin chops in pH per region in 2012. In both studies, there were significant differences in enhancement type in the PA, SE, SW, and WC regions for WBSF. However, in 2012, there was also a significant difference in enhancement type in the MA region for WBSF. Sirloin chops had significant WBSF differences in enhancement type for both years in the PA, and WC regions. Yet, in 2012 there were additional significant differences in enhancement type for sirloin chops in the EC, MA, NE, and SW regions. Blade steaks had no similar differences in 2012 and 2015 for enhancement type per region. In 2012, there were significant differences in the MA, PA, and WC regions for WBSF, but in 2015 there was a tendency difference in enhancement type in the PA region for WBSF. Therefore, from the two studies, some of the regions have similar enhancement type differences per region for different instrumental pork quality attributes for center-cut loin chops, sirloin chops, and blade steaks. Overall, the results from both studies suggest enhancing pork improves the pH value and also improves tenderness. However, it is muscle cut dependent and likely due to the type of enhancement solution(s) added by the processor.

Pork Quality Frequency Distributions

The frequency distribution of subjective color scores from 2012 and 2015 in-store and in-laboratory for enhanced and non-enhanced center-cut loin chops according to the National Pork Board Color Standards (NPB, 2011) are presented in Figure 3.1.

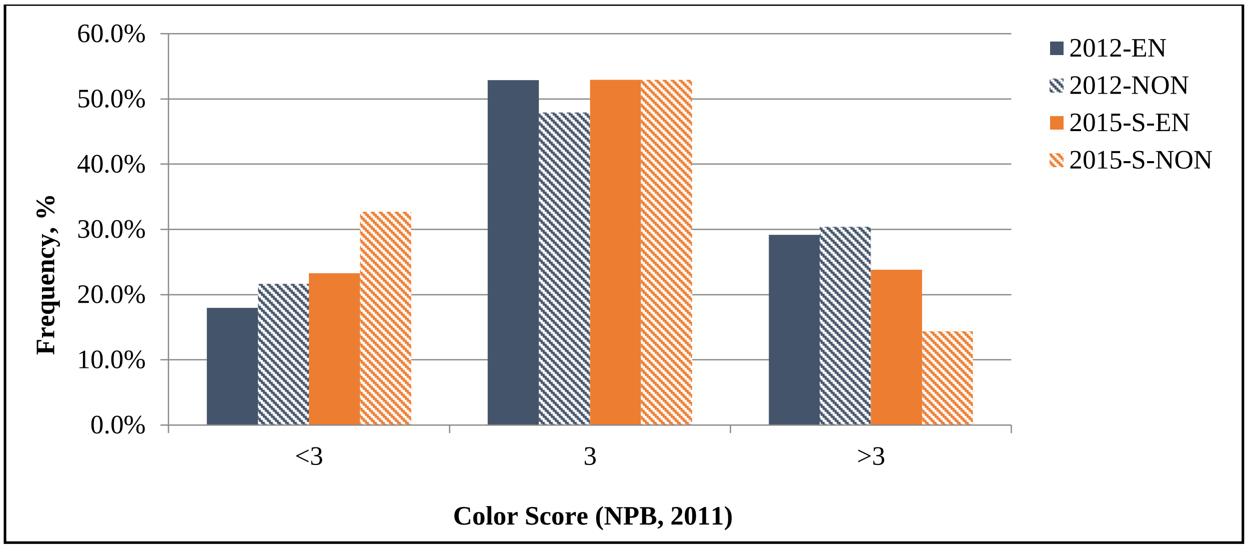

Figure 3.1. Frequency distribution of subjective color scores from 2012, and 2015 in-store (S), for enhanced (EN) and non-enhanced (NON) center-cut loin chops.

The mean subjective color score in 2012 was 3.12 (± 0.85), while in 2015 in-store the subjective color score was 2.85 (± 0.79). Approximately half of all center-cut loin chops evaluated having a color score of 3 (52.9 % for EN and 47.9 % for NON) in 2012, and (52.9 % for EN and 52.9 % for NON) in 2015. The frequency distribution amongst the in-laboratory subjective color scores between EN and NON center-cut loin chops showed little difference. Norman et al. (2003) separated boneless pork loins into three different groups based on subjective color standards (NPB, 2011) and showed 20.8 % of consumers selected pork with a color score of 1 or 2, 26.4 % selected pork with a color score of 3 or 4 and approximately half of the consumers (52.8 %) selected pork with a color score of 5 or 6. In 2012, 18.0 % of EN and

21.7 % of NON center-cut loin chops had a color score of 1 or 2. Moreover, 29.1 % of EN and 30.4 % of NON center-cut loin chops had a color score greater than 3. Whereas in the current study, 23.3 % of EN and 32.7 % of NON center-cut loin chops had a color score of 1 or 2. Moreover, 23.8 % of EN and 14.4 % of NON center-cut loin chops had a color score greater than 3.

Figure 3.2 presents the frequency distribution of subjective marbling scores from 2012 and 2015 in-store and in-laboratory for enhanced and non-enhanced center-cut loin chops according to the National Pork Board Marbling Standards (NPB, 2011). The mean subjective marbling score in 2012 was 2.48 (± 0.95), and in 2015 was 2.30 (± 1.07). The majority of center-cut loin chops in 2012 had subjective marbling scores of 2 or 3 (76.1 % for EN chops, respectively; 77.0 % for NON chops, respectively). Similarly, in 2015, a majority of center-cut loin chops had a subjective marbling score of 2 or 3 (56.1 % for EN chops, respectively, 67.5 % of NON chops, respectively). In 2012, a larger percentage of center-cut loin chops scored a 2 or 3, then in 2015. Cannata et al. (2012) reported when IMF was 2.5 % or greater tenderness and juiciness increased. Similarly, Fernandaz et al. (1999a) reported when IMF values reached 2.5 % juiciness and flavor was enhanced. Furthermore, Font-i-Furnols et al. (2012) recommended 2.2-3.4 % minimum of IMF improves eating satisfactoriness. Rincker et al. (2008) concluded nearly 50 % of consumers in a sensory panel selected pork loin chops in a case with the least amount of marbling, but said they would purchase pork that is leaner. Moeller et al. (2010) suggested IMF levels of 5-6 % would improve pork flavor, but contribute very little or have no influence on consumer’s perceptions of juiciness or tenderness attributes. Results from this current study, and in 2012 are in compliance with past literature results observing marbling pork quality sensory attributes, suggest that in the self-serve retail meat case nationwide, all cuts have marbling values that reinforce satisfactory eating quality, except for EN sirloin chops from the current study.

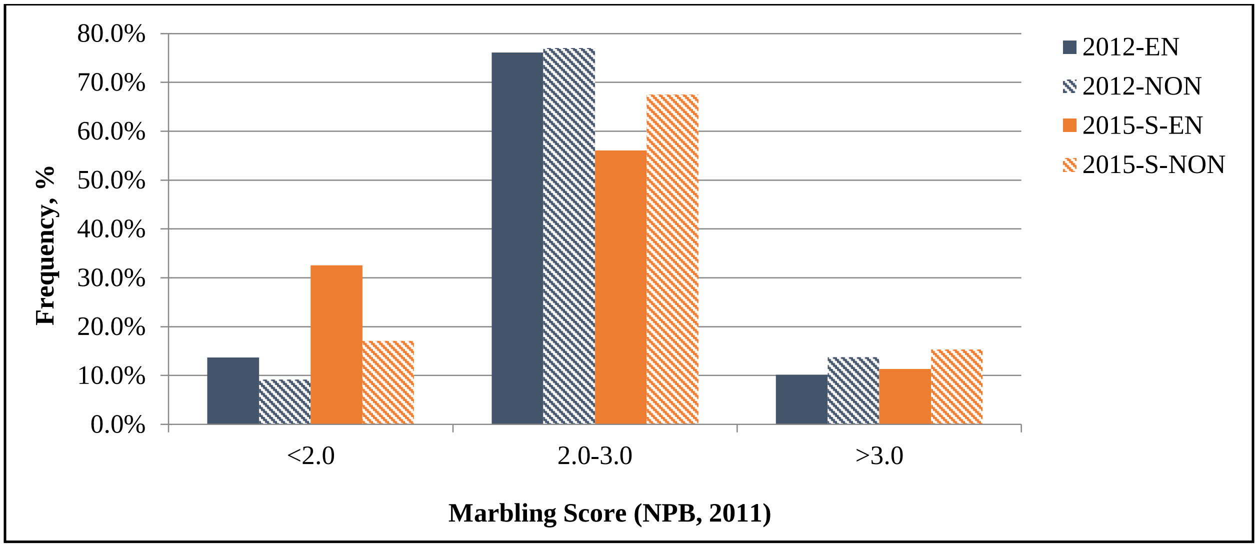

Figure 3.2. Frequency distribution of subjective marbling scores from 2012, 2015 in-store (S), for enhanced (EN) and non-enhanced (NON) center-cut loin chops.

The frequency distribution of Minolta L* values from 2012 and 2015 of enhanced and non-enhanced center-cut loin chops are presented in Figure 3.3. The thresholds are categorized as being less than or equal to a Minolta L* value of 52.00, in the range of 46.00 to 51.99, and greater than 46. In 2012, EN center-cut loin chops had 21.7 % in the Minolta L* value range of 46.00 to 51.99, 77.1 % of the chops had a Minolta L* > 52.00 and 1.2 % had a Minolta L* < 46.00. NON center-cut loin chops had 11.9 % of the chops in the Minolta L* value range of 46.00 to 51.99, 87.7 % of the chops had a Minolta L* > 52.00 and 0.5 % had a Minolta L* < 46.00. In 2015, EN center-cut loin chops had 24.0 % in the Minolta L* value range of 46.00 to 51.99, 75.1 % of the chops had a Minolta L* > 52.00 and 0.9 % had a Minolta L* < 46.00. NON center-cut loin chops had 13.2 % of the chops in the Minolta L* value range of 46.00 to 51.99, 86.6 % of the chops had a Minolta L* > 52.00 and 0.2 % had a Minolta L* < 46.00. Therefore, in 2012, there was a larger percentage of EN and NON center-cut loin chops that had a Minolta L* value > 52.00, and larger percentage of EN and NON center-cut loin chops that had a Minolta L*

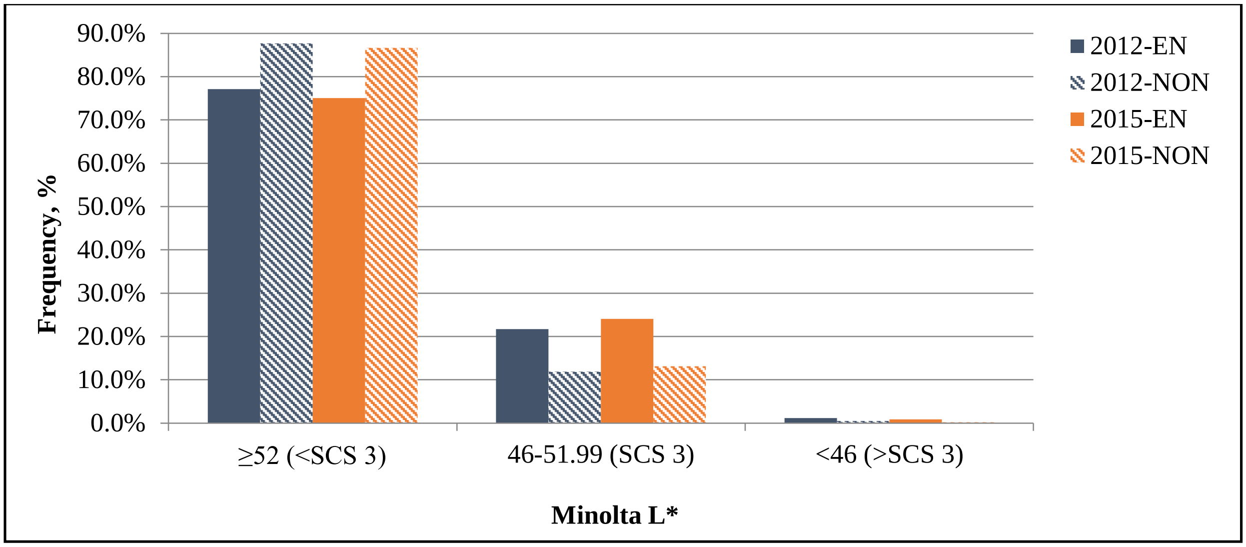

Figure 3.3. Minolta L* frequency distribution from 2012 and 2015 of enhanced (EN) and non-enhanced (NON) center-cut loin chops. Subjective color scores assigned to Minolta L* values are based on Meisinger et al. (1999).

< 46.00. But in 2015, EN and NON center-cut loin chops had a larger percentage fall in the range of 46.00 to 51.99. Overall, in both years, there is a larger percentage of Minolta L* values that fall >52.00, which is categorized as having a subjective color score less than 3, and a very small percentage regardless of enhancement type with Minolta L* values < 46.00. Thus, results indicate over the years, consumers are being offered a majority of lighter colored pork in the retail meat case.

The frequency distribution of pH values from 2012 and 2015 of enhanced and non-enhanced center-cut loin chops are presented in Figure 3.4. Within center-cut chops for 2012, 23.5 % of EN chops, and 43.9 % of NON chops had a pH between 5.50 and 5.79. A small percentage of EN Three fourths of EN center-cut loin chops (75.0 %) and approximately one fourth of NON center-cut loin chops (49.6 %) had a pH greater than 5.8, resulting in a large percentage of all center-cut loin chops that may have improved eating quality with pH alone as a quality classification. As anticipated, pH was greater for both years in EN center-cut loin chops then NON center-cut loin chops that were > 5.8. For both years a larger percentage of pH values

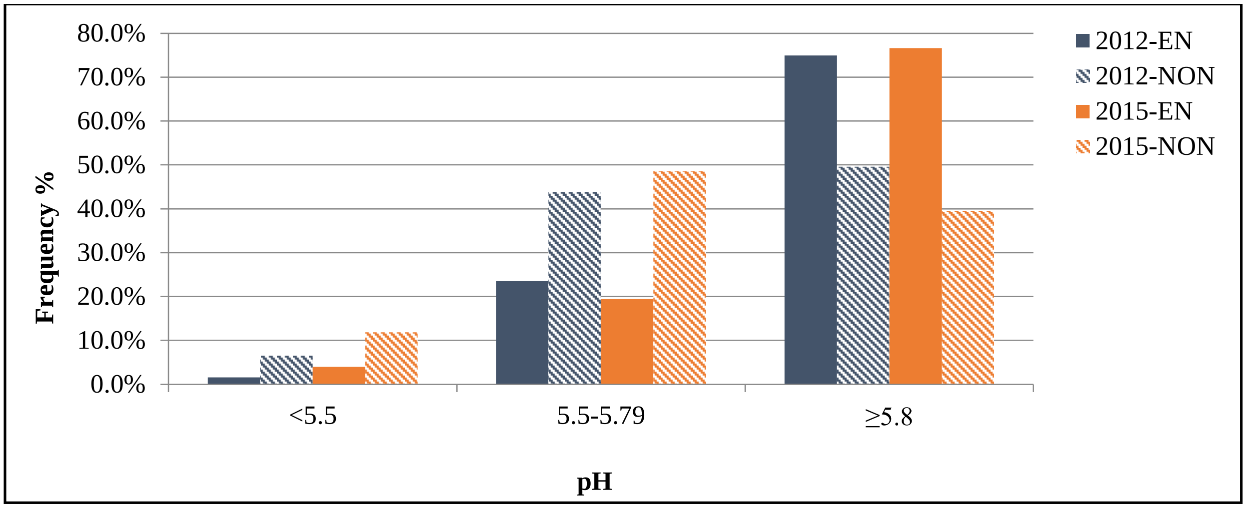

Figure 3.4. Frequency distribution of pH from 2012 and 2015 of enhanced (EN) and non-enhanced (NON) center-cut loin chops.

for NON center-cut loin chops fell in the range 5.5 to 5.79 than EN center-cut loin chops. Additionally, NON center-cut loin chops had a larger percentage of pH values < 5.5 for both studies. One explanation for the differences in enhancement type for pH is the addition of non-meat ingredients to the pork at the plant to create an enhanced product for retailers. Miller (2002) reported the addition of water, sodium or phosphates increases the pH that allows proteins to bind more free water, and less moisture on the cut surface, resulting in less light reflection and in turn appears darker. Moeller et al. (2010a) indicated pork loins with an ultimate pH value between 5.8 and 6.4 had positive sensory responses from a trained panelist. Thus, retailers have the option to present darker pork to consumers by enhancing pork.

The WBSF frequency distribution in 2012 and 2015 for enhanced and non-enhanced center-cut loin chops is presented in Figure 3.5. In 2012, over three fourths (75.4 %) of EN and approximately half (49.1 %) of NON center-cut loin chops had a WBSF value less than or equal to 24.5 N. A larger percent of NON center-cut loin chops had a WBSF in the 24.5 to 29.4 N range (29.6 % vs. 14.2 %, respectively) than EN center-cut loin chops. As well, a larger percent of NON center-cut loin chops had WBSF values > 29.4 N (21.3 % vs. 10.4 %, respectively) than

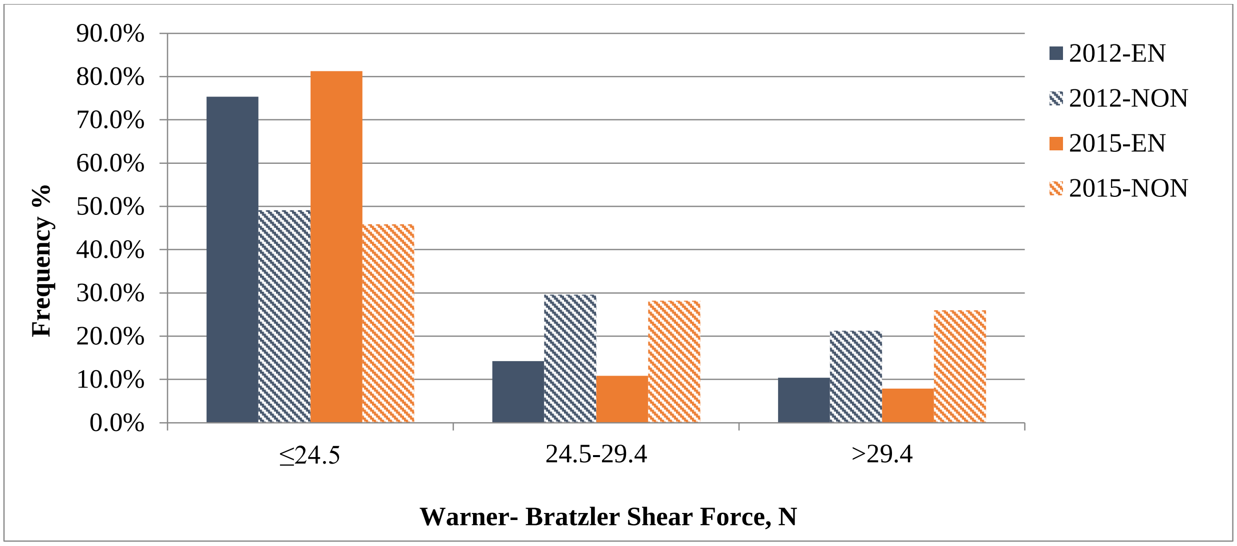

Figure 3.5. Warner-Bratzler Shear Force frequency distribution from 2012 and 2015 of enhanced (EN) and non-enhanced (NON) center-cut loin chops.

EN center-cut loin chops. In 2015, over three fourths (81.3 %) of EN and close to half (45.9 %) of NON center-cut loin chops had a WBSF value less than or equal to 24.5 N. A larger percent of NON center-cut loin chops had a WBSF in the 24.5 to 29.4 N range (28.2 % vs. 10.8 %, respectively) than EN center-cut loin chops. As well, a larger percent of NON center-cut loin chops had WBSF values > 29.4 N (26.0 % vs. 7.9 %, respectively) than EN center-cut loin chops. Therefore, there is slightly a larger proportion of EN center-cut loin chops that have a WBSF value < 24.5 N in 2015 then 2012. However, there is slightly a larger proportion of NON center-cut loin chops that have a WBSF value < 24.5 N in 2012 then 2015. Moeller et al. (2010b) determined consumers positively responded to WBSF values below 24.5 N, for tenderness-like, tenderness-level, juiciness-like, juiciness-level, and overall-like, but for every 4.9 N increase in WBSF values, their overall-like decreased by 4%. Thus, regardless of enhancement type, a majority of pork in the U.S. meat case is classified as tender due to the distribution falling below the threshold of 24.5 N reported by Moeller et al. (2010b).

Conclusion

Based on the results from this current benchmarking study, compared to the study being conducted three years prior, there are certainly differences and similarities. Specifically, subjective color score has reduced over the years (3.12 vs. 2.85, respectively), subjective marbling score has also reduced over the years (2.48 vs. 2.30, respectively). Instrumental pork quality attributes for EN product had higher pH values than NON, as well as were more tender (lower WBSF) than NON center-cut loin chops in both years. It is important to continue benchmarking pork quality at the retail level to identify how and what pork quality values are currently to make any necessary changes at each segment level in the swine industry to display what the industry is providing consumers at the retail self-serve meat case.

Literature Cited

Brewer, M. S., Zhu, L.G., & McKeith, F.K. (2001). Marbling effects on quality characteristics of pork loin chops: consumer purchase intent, visual and sensory characteristics. *Meat Science*, 59,153-163.

CIE (Commission Internationale de I'eclairage). (1978). Recommendations on uniform color spaces- color equations, psychometric color terms. Supp. No. 2 to EIC Publ. No. 15 (E-1.3L) 1971 (9TC-1-3), CIE, Paris, France.

Cannata, S., Engle, T.E., Moeller, S.J., Zerby, H.N., Radunz, A.E., Green, M.D., Baas, P.D., & Belk, K.E. (2010). Effect of visual marbling on sensory properties and quality traits in pork loin. *Meat Science*, 85, 428-434.

Fernandez, X., Monin, G., Talmant A., Mourot, J., & Lebret B. (1999) Influence of intramuscular fat content on the quality of pig meat- 2. Consumer acceptability of *m. longissimus lumborum*. *Journal of Meat Science*, 53, 67-72.

Font-i-Furnols, M., N. Tous, E. Esteve-Garcia, and M. Gispert. (2012). Do all the consumers accept marbling in the same way? The relationship between eating and visual acceptability of pork with different intramuscular fat content. *Meat Science* 91, 448-453.

Moeller, S.J., Miller, R.K., Edwards, K.K., Zerby, H.N., Logan, K.E., Aldredge, T.L., Stahl, C.A., Boggess, M., & Box-Steffensmeier, J.M. (2010b). Consumer perceptions of pork eating quality as affected by pork quality attributes and end-point cooked temperature. *Meat Science*, 84, 14-22.

Newman, D.J. (2012). National pork retail benchmarking study. Des Moines, IA. National Pork Board. Available from http://research.pork.org/Results/ResearchDetail.aspx?id=1760. Accessed September 8, 2014.

Norman, J. L., E. P. Berg, H. Heymann, and C. L. Lorenzen. (2003). Pork loin color relative to sensory and instrumental tenderness and consumer acceptance. *Meat Science*, 65,927-933.

NPB (National Pork Board) (2011). Official color & marbling quality standards. Des Moines, IA: National Pork Board.

Rincker, P. J., J. Killefer, M. Ellis, M. S. Brewer, and F. K. McKeith. (2008). Intramuscular fat content has little influence on the eating quality of fresh pork loin chops. *Journal of Animal Science*, 86, 730-737.

University of Nebraska – Lincoln. 2005. Porcine Myology. http://porcine.unl.edu/porcine2005/pages/index.jsp. (Last accessed 03 August 2015).

Wright, L.I., Scanga, J.A., Belk, K.E., Engle, T.E., Tatum, J.D., Person, R.C., McKenna, D.R., Griffin, D.B., McKeith, F.K., Savell, J.W., & Smith, G.C. (2005). Benchmarking Value in the Pork Supply Chain: Characterization of US Pork in the Retail Marketplace. *Meat Science*, 71, 451-463.

CHAPTER 4. OVERALL CONCLUSIONS AND IMPLICATIONS

Based on the results of this study, there is a great deal of pork quality variation which exists in the pork retail self-serve meat case nationwide. Consumers are being offered a wide variety of pork quality variation within package, retail store, and region and between enhanced and non-enhanced pork products, specifically for center-cut loin chops, sirloin chops and blade steaks. Benchmarking pork quality is essential to use as a tool to assist in meeting the National Pork Board's 2020 Strategic Plan Objectives to improve pork quality for consumers. Benchmarking pork quality is imperative to quantify what the swine industry as a whole is presenting to consumers at the retail level. Furthermore, it can be used as a benchmarking tool to implement or identify any changes necessary for swine producers, processors, and other industry stakeholders to improve pork quality since it has decreased in various quality attributes since the last 'National Pork Retail Benchmarking Study' and to ultimately increase pork demand and create a pork quality grading system in the future based on the variation observed in the present study.